How will the ecological quality status of benthos in coastal waters evolve?
ECOSTAT

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Gert Van Hoey, Jozefien Derweduwen, Sofie Vandendriessche, Koen Parmentier, Kris Hostens ***How will the ecological quality status of benthos in coastal waters evolve? – ECOSTAT -*** Final Report – Belgian Science Policy 2009 – 71 p – Research Programm: Action in support of the federal authority's strategic priorities -

Acknowledgements

- We thank all participants of the ECOSTAT workshop for their contributions to the project and the interesting discussions.
- Thanks to Hans Hillewaert for delivering pictures and figures.

Prepared for

Belgian Science Policy

In the framework of the “Action in support of the federal authority's strategic priorities”

AP5/00/033

Reference:

Van Hoey, G., Derweduwen, J., Vandendriessche, S., Parmentier, K., Hostens, K., 2009. How will the ecological quality status of benthos in coastal waters evolve (ECOSTAT)? Belgian Science Policy, Brussels . 63p

Contents

Summary

The European Water Framework Directive (2000/60/EC) (WFD) aims to achieve a good ecological and chemical status of European waters in 2015. This project focuses on the quality element macro-invertebrates (benthos) for the Belgian coastal waters (< 1 nautical mile). The Belgian coastal waters, belonging to the Scheldt river basin district, are subject to many anthropogenic pressures, such as eutrophication, coastal defence works, ship traffic and physical disturbance (fishery). The presence of these pressure factors may impair quality improvements in Belgian coastal waters, so it is unclear whether a good status for benthos can be reached by the deadline of 2015. If the WFD objective would not be reached, it would be possible to obtain a delay of 6 or 12 years (2021, 2027) or to set reduced environmental objectives. An application for delay or reduced environmental objectives and their reasons have to be motivated in the first Scheldt River Basin Management Plan of 2009. Therefore, there is a need to scientifically evaluate the ecological status that can be reached at the three determined deadlines (2015, 2021 and 2027) for the biological quality elements macro-invertebrates and to ground the reasons for asking a delay or reduced environmental objectives. The scientific knowledge (current measure programmes, ecological status of coastal benthos, relation between benthos and its environment, modeling possibilities, long-term benthos trends) needed for the evaluation of a realistic future ecological status are gathered during this project. An answer is formulated in the discussion section based on the gathered information and the discussion during an expert meeting.

Measure programmes

The environmental conditions along the Belgian coast are influenced by a number of rivers (Scheldt, Yzer, Seine, Somme, Rhine, Meuse), which are situated in different countries (France, Belgium, The Netherlands) and regions/governments (Flanders, Wallonia, Brussels, Federal Government Belgium). Therefore, the recovery of the ecological status of the Belgian coast strongly depends on the measures taken by these different countries and regions within their river basins. Their measure programmes are summarized in section 3. It can be concluded that there is a high similarity between the measure programmes of the different regions and countries, which focus on the same main topics (reduction of pollutants and restoration of natural hydrodynamics). The measure programmes were mainly based on existing national/regional plans, in turn based on other European directives. Most countries/regions mainly take extra measures for the protection against ground water and surface water pollution from households, industry and agriculture. The outlined measure programmes were quite abstract, but the projects under each measure type were defined on a local scale for some regions/countries. The Belgian Federal government has little authority concerning water policy so it depends on regional actions to improve the ecological/chemical status of the coast.

Ecological status of benthos

The ecological status of benthos is determined using the Benthos Ecosystem Quality Index (BEQI) (Van Hoey et al., 2007; Ysebaert et al, submitted). The BEQI evaluates at three levels: ecosystem (relation primary production/benthic biomass), habitat (habitat and eco-element area surface changes) and community (density, biomass, number of species, similarity changes within a benthic community). The BEQI has the aim to evaluate the changes of the current condition in relation to the predefined reference conditions for each parameter. The evaluation of the ecological status of the benthos is based on the monitoring data collected in autumn 2007. Based on a random stratified sampling strategy, 9 groups (each 0.6 m²) of 15 Van Veen samples were taken along the Belgian coastline representing the different habitats (the *Abra alba, Nephtys cirrosa* and *Macoma balthica* habitat) in the three zones. The reference period selected is the period 1994 – 2004, with a 10 year

temporal coverage and a very good spatial distribution along the Belgian coast. All reference samples were linked to the three habitat types.

The ecological status assessment of the benthos of the Belgian coast is based on level 1 and 3 of the BEQI. Level 2, which evaluates changes in habitat areas is not included, because no information of past and current habitat areas is available. Corresponding with the precautionary principle and due to the unbalance in the relation primary production and benthic biomass, the EQR (Ecological Quality ratio) of level 1 was set on 0.6 (good-moderate boundary) by expert judgement. The overall score at level 3 for the benthos at the Belgian coast, by averaging the parameter scores for density, number of species and similarity per habitat (*Abra alba*: 0.609; *Macoma balthica*: 0.533; *Nephtys cirrosa*: 0.750), was 0.631, which means a good status. When combining the different levels, the EQR score for the Belgian coast was 0.62, which means a good status for the Belgian coast for the quality element benthos. However, a lower ecological status was found for some habitats or areas (east coast). This indicates that there were some pressures on the benthos in the coastal area, which prevented the maintenance/development of a 'healthy' benthic ecosystem along the entire Belgian Coast.

Relation between benthos and its environment

The linking between the benthic parameters (density, biomass, species richness and diversity) and anthropogenically influenced environmental parameters (nutrients, organic matter, oxygen, turbidity), parameters with an anthropogenic origin (heavy metals, chemical contaminants), fishery and climate impact were investigated. A focus on these parameters enables the evaluation of the effects of any reduced anthropogenic influences on the benthic characteristics. A lot of variables influence each other (e.g. nutrient → phytoplankton variables). The benthic respons to different environmental variables is not always straightforward and depends strongly on the region, type of habitat, intensity of the pressure, hydrodynamic conditions, the resilience of the benthic animals, etc… . The main patterns in benthic responses to changing environmental variables were outlined in this section, with some examples.

Modelling possibilities

The two main types of modelling were static and dynamic models. Static models were used to explain the occurrence of species or benthic characteristics under certain environmental conditions, but they do not predict or reflect the patterns in benthic characteristics in relation to changing environmental conditions. Dynamic models implement this and were ecosystem models that quantify characteristics within the ecosystem (chemical, physical and biological). This type of ecosystem modelling is not static in time but is still restricted in their spatial resolution (box models). This dynamic modelling approach with benthos is in a preliminary phase. Most of these 3D-models used in the greater North Sea introduced a benthic system for nutrient remineralisation by indirect mechanisms or used up to four explicit state variables for nutrients in the benthic bottom layer (e.g. MIRO&CO model), except the ERSEM models, which has real zoobenthos variables. The potentials to use these modelling approaches were outlined in this section. There can be concluded that it is possible to include a biological benthic compartment to make predictions for benthic parameters based on changing processes in the pelagic system and that research should further focus on it. Therefore some recommendations to improve the knowledge on this topic were outlined.

Long-term benthos trends

Benthos in coastal regions is subject to strong natural variability (seasonal and year-to-year). Long-term analysis of benthos characteristics can help to understand how this trend can influence the ecological status of the benthos. Trends in benthic parameters were evaluated based on long-term data over 30 years at three coastal stations (120, 140, 700), monitored by ILVO. It seems that the benthic characteristics in the Belgian coastal region are rather stable, with some fluctuations due to the dominance of certain species during a certain period. At station 700, the density, number of species and biomass decreases steeply per decade. For stations 120 and 140, the density remained stable or increased slowly, whereas the biomass was highest in the 90's. The number of species increased slowly. The variation in the benthic parameters for the stations 140 and 700 were greater than at station 120, which were indications of instability in this area. Only station 700, nearby the harbour of Zeebrugge, showed strong changes over the three decades, with a more diverse mud community in the 80's, characterised by structuring species (*Polydora spp., Corophium, Petricola pholadiformis*). This type of muddy community has disappeared and was replaced by a very poor benthic mud community (opportunistic species, like *Cirratulidae spp* and *Oligochaeta spp*) from 2000 onwards. The underlying causes for this steep decrease in density, biomass and number of species are unclear and needs more investigation, but it is likely that anthropogenic influences were responsible (eutrophication?, harbour of Zeebrugge?, dredging?).

Discussion

Advices were given on the following questions, based on the gathered information and the conclusions of the expert meeting:

1) Is it possible to reach/maintain the good ecological status of benthos in the Belgian coastal waters by 2015,

The current overall ecological status (ES) of benthos in the Belgian Coastal water is good, but in some zones and habitats a moderate status was observed. Especially at the east coast, impoverished benthic conditions were observed. It seems that, for the moment, the favourable conditions at the west coast compensate for the more impoverished conditions at the east coast. Reasons for this situation can be related to eutrophication, harbour of Zeebrugge or physical disturbance (fishery, dredging) and need further investigation.

Based on the current knowledge of the benthic experts and the observed benthic patterns along the coast, it can be expected that the current ecological status for benthos will hold for at least some years (until 2015). This prediction is based on the current level of the anthropogenic pressures, which are not expected to result further in drastic changes in the benthic characteristics compared to the defined reference conditions. Re-evaluation of this statement is necessary when the current pressures should intensify or change. Furthermore, it is advisable to determine the current ecological status based on benthic data covering more than one year.

2) what will be the ecological status of benthos at the end of each preset period (2021, 2027),

The benthic experts launched the hypothesis that the benthic system along the Belgian coast will not change drastically in the future, but that climate change, the occurrence of invasive species and changes in the anthropogenic impacts can alter this statement and that re-evaluation of it is necessary.

3) are the present measures adequate or are additional measures needed to reach these objectives

During the expert meeting, the advice was formulated to issue additional measures so that, despite the present good overall ecological status of benthos, additional ameliorations (especially at the east coast) can still be achieved. Based on the measure programmes in the Scheldt river basin district (section 3), it can be concluded that the current upstream measures mainly tackle the eutrophication and dangerous substances problem. The eutrophication problem will not readily be solved in the Belgian Coastal waters based on the current measures and extra effort is advisable. The problem about the dangerous substances will not lead to problems in marine waters, except PAH's and TBT, for which action has to be undertaken. For tackling the anthropogenic activities (dredging, fishery and coastal defence works), which are within the jurisdiction of the Flemish Government; consultation on a regional and national level should be continued and intensified. As outlined in the federal coastal management plan, the government has little authority to take direct actions to improve the ecological status of the coast. They can do something in the management plans of marine reserves, under the MMM-law, the European Marine Strategy Directive and stimulating research activities.

4) what should the reduced environmental objectives be (if necessary)?

Based on the outcome of this project, the immediate formulation of reduced environmental objectives seems not necessary. If necessary, the best way to reduce the environmental objectives is by reducing the good/moderate boundary to the level of the poor/moderate boundary for a certain time.

1 Introduction

The European Water Framework Directive (2000/60/EC) (WFD) aims to achieve a good ecological and chemical status of European waters in 2015. The ecological status has to be evaluated for lakes, rivers, transitional waters and coastal waters based on various quality elements (biological, chemical and hydromorphological).

This project focuses on the quality element macro-invertebrates (benthos) for the Belgian coastal waters (within a range of 1 nautical mile from the coastline). The Belgian coastal waters, belonging to the Scheldt river basin district, are subject to many anthropogenic pressures, such as eutrophication, coastal defence works, ship traffic and physical disturbance. The presence of these pressure factors may impair quality improvements in Belgian coastal waters, so it is unclear whether a good status for benthos can be reached by the deadline of 2015. If the WFD objective would not be reached, it would be possible to obtain a delay of 6 or 12 years (2021, 2027) or to set reduced environmental objectives. An application for delay or reduced environmental objectives and their reasons have to be motivated in the first Scheldt River Basin Management Plan of 2009. An application for a delay or a reduction of the environmental objectives can be formulated following a deviation of the WFD objective resulting from:

- natural circumstances, such as the low response time of the water system, or the later release of substances from the sediments
- technical reasons: time for research, administrative procedures or the lack of techniques to detect or reduce certain substances.
- economical reasons: disproportional costs of the measures, or an unacceptable social impact.

Therefore, there is a need to scientifically evaluate the ecological status that can be reached at the three determined deadlines (2015, 2021 and 2027) for the biological quality elements macro-invertebrates and to ground the reasons for asking a delay or reduced environmental objectives. The scientific knowledge needed for the evaluation of a realistic future ecological status will be gathered during this project.

Attempts to predict the future ecological state of ecosystem components (like benthos) are fraught with difficulty, particularly over decadal time-frames, due to the high variability and uncertainties in modelling. A prediction is a statement about the nature of an ecological condition in unknown circumstances and is mainly derived from a model (Underwood, 1990). The composition of benthos is mainly determined by sedimentological, geomorphological and hydronomical parameters (Snelgrove & Buttman, 1994; Degraer et al., 2002; Van Hoey et al., 2004). The relation between the benthos and other parameters like nutrients, organic matter, chlorophyll A and oxygen concentrations are so far hardly studied for the Belgian coastal waters. Knowledge of the relation between benthic parameters and environmental variables may allow us to predict changes or trends in benthos. Historical long-term data are also very valuable in this case. Therefore, this project will focus on gathering all necessary scientific information to ground the prediction of the ecological quality status of benthos in the future, with a focus on the usability of existing models and long-term trends of benthos. Furthermore, this project will incorporate the knowledge of Belgian and Dutch experts in the discussion.

2 Objectives

The main goal of the project is to deliver scientific support to the government by answering the following questions:

> 1) Is it possible to reach/maintain the good ecological status of benthos in the Belgian coastal waters by 2015?
>
> 2) What will be the ecological status of benthos at the end of each preset period (2015, 2021, 2027)?
>
> 3) Are the present measures adequate or are additional measures needed to reach these objectives?
>
> 4) What should the reduced environmental objectives be (if necessary)?

To answer these questions, the project will deliver a scientifically based evaluation of the ecological status that realistically can be reached over the three predetermined terms (2015, 2021, 2027) for macro-invertebrates (benthos) in the Belgian coastal waters based on the current planned measures of the concerned regions. Therefore the project includes:

1) An overview of the present measures taken within the Scheldt river basin district
2) A collection of following scientific information
    a. Present ecological status of the benthos in the Belgian coastal zone
    b. Relation between benthic parameters (density, biomass, number of species) and environmental conditions
    c. Modelling approaches
    d. Long term trends of coastal benthos
3) An expert meeting and discussion

3 Present measures taken within the Scheldt river basin district

The environmental conditions along the Belgian coast are influenced by a number of rivers (Scheldt, Yzer, Seine, Somme, Rhine, Meuse), which are situated in different countries (France, Belgium, The Netherlands) and regions/governments (Flanders, Wallonia, Brussels, Federal Government Belgium). Therefore, the recovery of the ecological status of the Belgian coast strongly depends on the measures taken by these different countries and regions within their river basins. The main river influencing the Belgian coast is the Scheldt; the Scheldt river basin district is illustrated in figure 1. All Belgian regions and neighbouring countries have formulated basic and supplementary measures in the framework of the WFD in order to achieve a good ecological status for their waters. These regions and countries were working together in the international Scheldt commission (Scheldt Treaty of Ghent 03/12/02; ISC) to compile all the necessary information on the level of the Scheldt River Basin District. In this international context they define six significant water management issues within PA3 working group on coast- and transitional waters (box 1).

The types/groups of measures taken within the Scheldt river basin district by the different countries and regions are summarized in this section. First, an overview of the main pressures affecting the Belgian Coastal area is summarized. Based on this information, expert judgement and literature knowledge, it will be evaluated whether these measures can have an impact on the ecological status of the Belgian Coast at different scales (table 2):

- Considerable negative effect (--): permanent and extensive
- Limited negative effect (-): small and permanent or limited/considerable but temporal
- No effect (0)
- Limited positive effect (+):small and permanent or limited/considerable and temporal
- Considerable positive effect (++):permanent and extensive

The influence of the measures on the ecological status of the Belgian coast is described from the viewpoint of the biological quality elements phytoplankton and benthos (see tables). Some measure groups will have an influence on the chemical status of the waters, which will be mentioned separetely. Measures with a particular influence on the ecological status of benthos are highlighted. This evaluation is rather rough, because the measure topics were broadly defined and their results depend strongly on the specific actions taken within each topic.

This summary list of measures and management actions are then be used as a basis to answer question 3 of the objectives.

Box 1. Significant water management issues for the Scheldt River basin district, determined by the PA3 working group (coast and transitional water group) within ISC

1. Improvement of the chemical and biological water quality
2. Investigation on the possibilities to improve the mud quality
3. A coordinated control on Scheldt specific pollutants and their reduction.
4. Information, measurement protocols and evaluation methods exchange and improving the comparability
5. Regulating good management for the implementation of the WFD
6. Making a link with the management of the SACs (e.g. Habitat- and Bird directive) and the European Marine Strategy Directive proposal

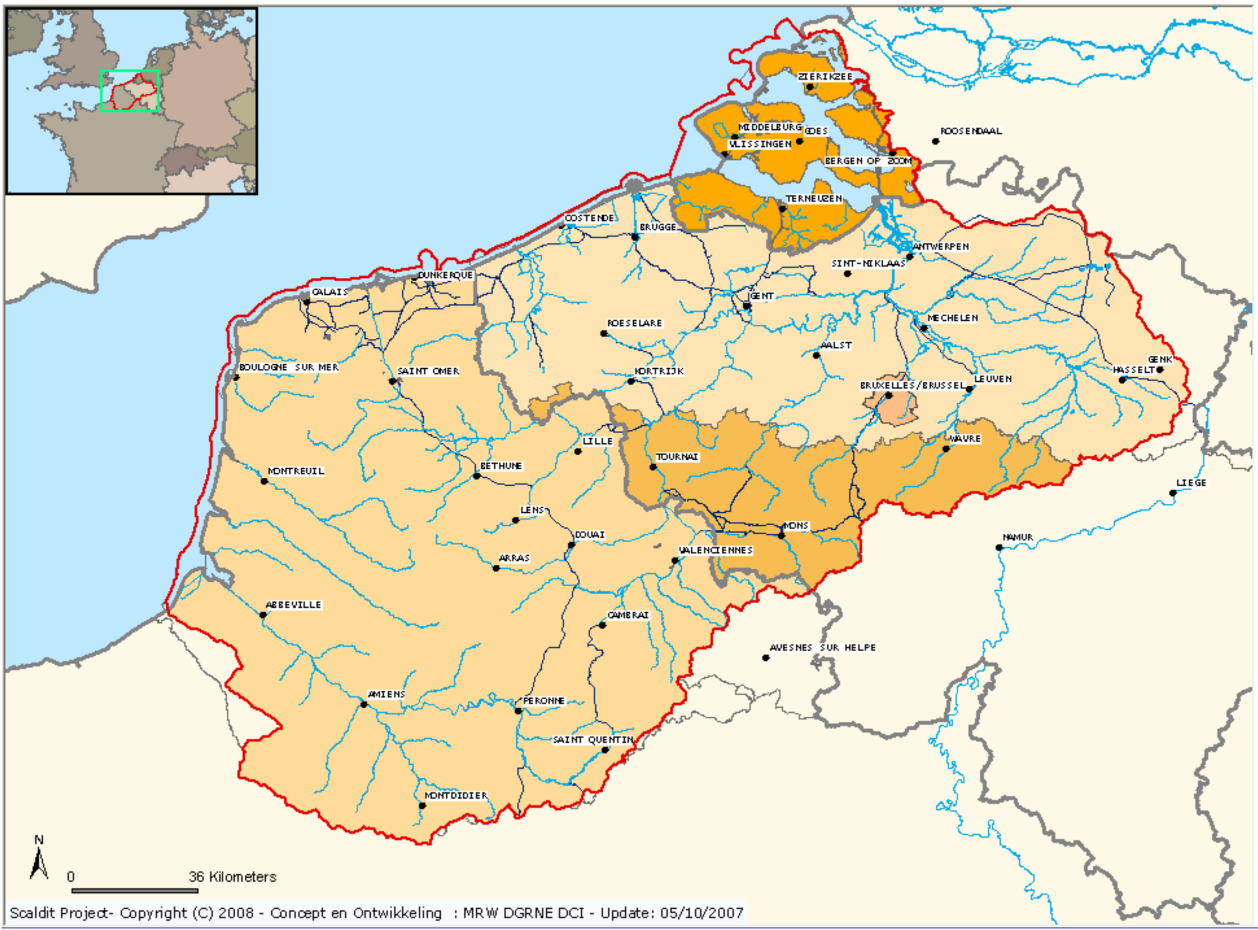

Figure 1. Map of the Scheldt river basin district, with indication of the different regions and countries involved in this district.

3.1 Anthropogenic pressures affecting the Belgian Coastal waters

Each country has had the task to outline and quantify the main anthropogenic pressures in their waters, following article 5 of the WFD. The text section below is mainly based on the article 5 report of the Federal State of Belgium concerning its territoral waters.

1) Terrestrial sources of pollution (direct or diffuse)

The terrestrial pollution input (nutrients such as nitrogen and phosphorus, heavy metals and chemical substances such as PCB and TBT) can be the result of direct discharges to sea or of diffuse sources (rivers, atmosphere). Direct discharges were forbidden by the MMM-law of 1999 (Wet Marien Milieu), but were negligable in previous years. The discharge weights from rivers/canals to the Belgian marine waters for some elements are summarized in table 1. From the table, it can be deduced that the Scheldt River is the main contributer for all elements. The atmospheric deposition amounts up to 30% of the river supply for nitrogen, and is comparable for cadmium and lead.

The anthropogenic pressure of pollution, more particularly of nutrient supply, causes changes in the fysico-chemical status of the phytoplankton ecosystem in the Belgian Coastal area (Rousseau et al., 2008) and indirectly influences the benthos. This causes eutrophication problems in the Belgian Coastal waters. Heavy metals and chemical substances can accumulate in animal tissues, causing mortality and a disturbed reproduction. River inputs have a more local impact compared to atmospheric deposition.

Table 1. Average yearly loads in the Belgian coastal area and the river Scheldt (Article 5 report) expressed as tons (t) or kilograms (kg)

Element	Average yearly load 1991-2002			
	Coastal area			Scheldt
	West	Middle	East	
Cadmium	0,05 t	0,4 t	0,2 t	3,8 t
Mercury	0,01 t	0,01 t	0,03 t	1,2 t
Copper	1,1 t	1,4 t	1,8 t	66,8 t
Lead	0,5 t	0,4 t	1,2 t	51,4 t
Zinc	4,9 t	4,3 t	10,3 t	335 t
Lindane	18,6 kg	3,1 kg	4,8 kg	56 kg
Total nitrogen	3,6 kt	2,4 kt	4,7 kt	43 kt
Total phosphor	0,3 kt	0,3 kt	0,6 kt	3,4 kt

2) Shipping

The impact of shipping is mainly related to oil pollution, due to accidents or dumping and waste discharge in the marine waters. Based on the measurements of MUMM, the oil pollution and the total yearly oil volume have been decreasing in the Belgian waters since 1992. The impact on the benthic life is minimal and can be locally higher due to shipping accidents.

3) Dumping of dredged material

The Belgian harbours and fairways of the ships need dredging activites to maintain their function. This dredged material is dumped at 5 locations in the Belgian waters, causing temporal impoverishment of the benthic fauna at high dumping frequencies (Lauwaert et al., 2008).

4) Fishery

The Belgian Coastal zone is intensively fished, mainly by beam trawlers. Next to the professional fishery, the recreational fishery is also strongly active in the coastal zone (e.g. shrimp fishery). As a consequence, the Belgian Coastal area is strongly impacted by bottom destructive fishery activities, disturbing the benthic life. The typical benthic communities are subject to changes and , promoting the presence of short living, robust and opportunistic species.

5) Invasive species

In the Belgian coastal area, the introduction rate of new species is high due to human transport activities (ballast waters; fouling species) and climate change. Approximately 100 introduced species have been found in coastal waters and harbours (information MUMM and VLIZ). In the benthic communities along the coast, mainly *Ensis directus* and *Crepidula fornicate* have become rather dominant.

6) The ammunition dumping area 'Paardemarkt'

After the first world war, a high amount (35.000t) of ammunition was dumped at a small area (3km²) at the east coast (the 'Paardemarkt'), with some grenades containing a chemical load. The presence of sulphur mustard gas and arsenic locally contaminate the sediments and benthic fauna.

7) Coastal defence works

Due to sea level rise and the protection against coastal flooding, coastal defence works (mainly beach nourishment) have been intensified during the last years. Beach nourishment has a temporary effect on the benthic communities (Speybroeck et al., 2008).

Summary

The main anthropogenic pressures affecting the Belgian Coastal waters were summarized above and can be ranked according their importance:

- Intensive fishery activities, causing bottom disturbance
- Eutrophication
- Dredging activities for the harbours and fairway of ships, dumping of dredged material
- Occurrence of invasive species
- Coastal defence works
- Waste discharge from the main harbours (Zeebrugge, Blankenberge, Oostend, Nieuwpoort)
- Occurrence of dangerous substances (heavy metals, PCB, TBT, PAK, …) in the water/sediment and animal tissues
- Shipping
- The ammunition dumping area ‘Paardemarkt’

3.2 Belgium

In this section, the measure programmes of the Federal Governement, of Flanders, Wallonia and the capital region were outlined. To understand the implementation of the measures taken within the WFD for the River basin district of the Scheldt within Belgium, the authority structure in Belgium and the division of competences is outlined in box 2.

3.2.1 Federal

The Belgian policy framework for the protection of the marine environment is determined by the law of 20 januari 1999 for the protection of the marine environment in the marine areas under the jurisdiction of Belgium (BS 12 march 1999), abbreviated as the MMM-law (Wet Marien Milieu Marin). This law forms the basis to protect the Belgian waters against sea related pollutions and allows nature conservation, nature recovery, and nature development. The law also implies the need for licences for architectural, industrial, commercial and publicity-related activities at sea.

The program of measures is described below and is summarized in table 2.

Box 2. Authority structure of Belgium.

Belgium is governed by various authorities (Federal state, communities, regions, provinces, municipalities), each with their own competences. The competences of the Federal State, the communities and the regions are laid down in the Belgian Constitution and the Special Law of 8 August 1980 on institutional reforms. Pursuant to this constitutional division of competences the three Regions (Flemish region, Walloon region and Brussels capital region) are fully competent for the implementation of the WFD regarding water policy (including drinking water policy), land development, nature conservation and public works and transport
on their territory (on land) and the Federal State is fully competent for the implementation of the WFD on their territory (on sea) and for product regulation (and authorisations to put products on the market), protection against ionising radiation, including radioactive waste, the economic aspects of drinking water provision (i.e. the establishment of maximum prices and the approval of price increases) for the entire Belgian territory. The federal and regional competences are exclusive, equivalent material competences, without any hierarchy. A federal or regional legal norm has the same legal value.
The Belgian coastal zone belongs to the international Scheldt river basin district. This river basin district is governed by the Netherlands, France, the three Belgian regions and the Federal State Belgium. This means that there is a need for coordination between the different countries and regions. Coordination takes place in the International Scheldt Commission and is formalised in the Scheldt Treaty of Ghent 03/12/02, concluded by the three countries and the three Belgian regions (the regions are competent to sign and ratify treaties within their material competences).
A second agency for coordination at internal Belgian level (Federal state and regions) is CCIM (Coordination Committee International Environmental Policy). This is established by the "Cooperation agreement of 5 April 1995 between the Federal State, the Flemish Region, the Walloon Region and the Brussels Capital Region regarding international environmental policy". This cooperation agreement is legally binding for these authorities after being ratified by each authority by law, decree or ordinance. The secretary and presidency of the CCIM is being acted by the Federal State. The CCIM has established several technical working groups that are responsible for the coordination of specific environmental issues. Within this framework, the CCIM Steering Group Water (presided by the Flemish Region) is the consultative body that is in charge of the necessary coordination of the implementation of the Water Framework Directive between the different competent authorities in Belgium. Cf. article 1, 3° of the cooperation agreement: "the consultation in order to come to a coordinated execution of recommendations and decisions of international organisations". The coordination at these two levels makes it possible to compare the used methods, confronting each other with each others actions and strive for coherence and comparability within the Scheldt river basin district.

➔ 1. Measures taken based on the European water protection legislation

A summary of the different European directives that influence the protection of the Belgian coastal environment is given below.

- *European Bird and Habitat Directive (79/409/EEG, 92/43/EEG)*
  A part of the Belgian coast (< 1 nautical mile from the coastline), subject to the WFD, is situated in areas designated as Bird and Habitat areas (the Trapegeer – Stroombank area, SBZ1, SBZ2, SBZ3). The marine reserve located to the east of the harbour of Zeebrugge (Baai van Heist) is entirely situated in the 1 nautical mile zone of the Belgian Coast. Therefore, the policy concerning these marine protected areas can influence the ecological status of the Belgian coast by prohibiting or regulating certain activities. The overall rule in the areas for nature conservation is that all activities are allowed, except those prohibited by the law. The activities forbidden in those areas are mariculture, bird and marine mammal hunting, the introduction of non-indigenous or genetically manipulated species, dumping, direct discharge in marine areas and industrial activities. In the marine reserve of the Baai van Heist, all activities are prohibited, except for shipping, digging of grooves, elevation of the seafloor, placement and maintenance of cables and pipelines and activities which were regulated by the user's agreements. It can be concluded that in these nature conservation areas, most

activities (fisheries, dredging, sand suppletions, digging) which have an impact on the benthos are still allowed and will influence the ecological status of the benthos in the coastal area. Some activites (dredging, sand suppletions, digging) have a more local impact on the ecosystem, while fisheries influence the entire ecosystem.
The Federal Governement has outlined a strategy in its policy plans for the marine protected areas to bring the species and habitat types in a favourable state of maintenance. Hopefully, measures will be included that can (in)directly help the maintenance or improvement of the ecological status of the benthos.

- *European directive on the assessment of the effects of certain public and private projects on the environment (97/11/EG)*
  Different laws and royal decrees enabled the implementation of this directive by regulating the procedure for the planning of projects and programs on the Belgian Continental Shelf and their effect on the environment. These laws require that new activities planned in the Belgian coastal area may not negatively influence the status of the ecosystem. This directive is particularly important for the Belgian coast in case of coastal defence works.

- *European directive for the introduction of plant protection products on the market (91/414/EEG)*
  There is a programme for the reduction of pesticides and biocides to reduce the risk and the use of these substances. On the long run, this will lead to a reduction of these substances in surface waters, both freshwater and marine and helps to improve the chemical status.

- *The daughter directive of the European dangerous substances (76/464/EEG)*
  Direct discharges of listed dangerous substances are forbidden by the MMM-law. The different regions take measures to reduce the discharge of these substances in the Scheldt river basin (see further). This will help to reduce the concentration of heavy metals and other chemical substances in the water, sediments and tissues of the marine fauna (benthic animals) and will positively affect mainly the chemical status.

- *European shellfish waters directive (2006/113/EG)*
  This directive sets the minimum standard for the water quality (toxic algae) for shellfish cultivation or harvesting and will not directly influence the ecological status of the benthos.

➔ 2. Measures for point discharges and other activities influencing the water state.

- Direct discharges of any substance in the marine environment are forbidden by the MMM-law. Measures were taken upstream by the different regions to minimize the effects of discharges (see further).
- The dumping of dredged material is regulated by licences, which regulate the quality and quantity of the dredged material. Impact studies on the ecosystem at dumping sites were conducted by BMM and ILVO. Dumping of dredged material mostly has a temporal effect on the benthos. In the case of intensive dumping activities, this can lead to an impoverishment of the bottom fauna (benthos, epifauna and demersal fish) and to changes in the local sedimentology. One dumping site (Zeebrugge) is situated nearby the Belgian coastal area (within 1 nautical mile of the coastline) and is intensively used, resulting in a local negative impact on the benthic fauna (Lauwaert et al., 2008).

→ 3. Measures related to priority substances

Direct discharge of priority substances (pesticides, biocides, industrial polluted substances, heavy metals, PCB's, TBT, PAH's) were forbidden by the MMM-law. Upstream, measures were taken by the different regions (see further). The Federal Government is only authorized to determine the procedure to bring these products on the market and to control their use. Laws were implemented to control the concentrations of these substances or to prohibit their use. PCB's and TBT will be forbidden in the near future, but tracers of these products will remain present in the environment for a longer time. TBT is responsible for the imposex phenonomen for gastropods and is found in high concentrations nearby the Belgian harbours (see 4.2.6).

These measures will help on a long term to reduce the concentration of these substances in water, sediments and in the tissues of marine fauna (benthos) and will positively affect the ecological and chemical status.

→ 4. Measures to avoid or reduce the effect of accidental and operational pollution

The Federal Government has to take preventive measures in cases of ship pollutions (eg. oil spill). Different Federal and regional instances are involved:

- Air surveillance to control pollution events on the BCS (Bonn agreement 83/89; Marpol-agreement (73/78))
- Operational unit for challenging an oil spill
- Prohibition of dumping of any substance, (exceptions defined by law) (Agreement of London, 1972 and the protocol of 1996)
- Control of the state of ships, especially oil tankers
- Reduction of rubbish dumping by providing the harbours with facilities for acceptance of ship rubbish (regional authority)
- Creation of a policy for the recovery of environmental damage and disturbance

These measures will help to reduce and avoid the risk of accidental pollutions along the Belgian coast and to prevent a sudden decline of the ecological/chemical status.

→ 5.-6. Supplementary measures to reach the environmental objective of the WFD

Because the biological and chemical status of the Belgian coastal waters is not good and because it is doubtable that a good status can be reached by 2015, a prolongation of the term will probably have to be requested. Therefore, supplementary measures should be taken to improve the status by

- amplifying integrated coastal zone management (ICZM) in Belgium
- A continuation of the Fishing for Litter project, aiming to include local fishermen in the removal of marine litter. This will also reduce the impact of 'ghost fishing' (passive fishing by roaming litter).
- The stimulation of research that helps to implement the WFD. Different research projects, financed by the Federal Science Policy, address topics that investigate the impact of anthropogenic activities (mainly eutrophication) on the marine ecosystem (e.g. AMORE III, LUSi, TIMOTHY).

→ 7. Measures to avoid the increase of the pollution of marine waters

These measures deal with prevention activities to avoid the introduction of invasive species via ballast water. "The convention for the control and management of ships' ballast water and sediments" has not yet been ratified by the Belgium Government. However, the deliberate introduction of invasive species by ballast water of ships is forbidden by the MMM-law.

➔ 8. Climate check

A national climate plan has been put into action and research related to the impact of climate on the marine environment is being carried out (mainly addressing issues related to economy, coastal defence works and to some extent eutrophication (AMORE III)). The increase of temperature and rainfall intensity will influence the ecological quality of water systems at different levels (shift of species, mismatches in life cycles, increase of eutrophication, increase of run off of hazardous substances and soil particles). Consequently, more measures should be taken to reduce the effect of eutrophication, which is a major issue at the Belgian coast, with changing climate.

➔ Summary

No measures were implemented that can directly ànd positively influence the ecological status of the Belgian coast, particularly for the benthos. The main anthropogenic pressures affecting the ecological status of the Belgian coast were fishery and eutrophication (see section 3.1). To reduce these impacts, the Belgian Federal Government strongly depends on related measures taken by the regions and neighbouring countries, especially for tackling the euthrophication. Fishery management is the authority of the Flemisch government. The government can only consultate and try to influence these actors to implement the measures in such a way that the Belgian coast would profit from it. Therefore, it is advisable to amplify the consultations on this topic in the International Scheldt Commission and in the CCIM on a national level (see box 2).

Detailed information about the programme of measures taken by the Federal Governement of Belgium, can be found at
https://portal.health.fgov.be/portal/page?_pageid=56,7432417&_dad=portal&_schema=PORTAL.

3.2.2 Flanders

The water management in Flanders is regulated via 'het decreet Integraal Waterbeleid (DIW - decree of integrated water policy)' of 2003. This law consists in the transposition of the European Water Framework Directive into the Flemish law and describes how the water management should be organized.

The river basin management plan of Flanders focuses on the surface waters of larger-sized water systems and originates from the plans made in different regional river plans. The measures were grouped into 8 units (Table 2). For each unit, basic and supplementary measures were listed.

➔ 1. European water protection legislation

The measures taken within the context of other European (environmental) directives are integrated into the measures programme of the WFD. Measures taken on the level of Flanders of the following European directives could have an influence on the ecological status of the Belgian coast:

- the nitrate directive (91/676/EEG), for reducing the eutrophication in the coastal area.
- the directive concerning the handling of urban sewage (91/271/EEG), for reducing the eutrophication in the coastal area
- the directive of plant protection products (91/414/EEG), for reducing the occurence of chemical pollutants.

Measures taken within these directives will influence the ecological and chemical status of the coast and the status of the benthos.

➔ 2. Cost recovery principle and polluter pays principle

In this unit, measures were outlined to recuperate parts of the costs for the water management from different users (the industry, households and agriculture). These measures are based on the principle that the polluter has to pay.

No basic or supplementary measures under this topic will have an influence on the ecological/chemical status of the coast, but they will help to make other measures (e.g. concerning water treatment) affordable.

➔ 3. Sustainable water use

This group of measures aims to make the water use more sustainable and is based on changes in behavior, technological changes, a price- and tax policy with the aim of an economical water use and the use of alternative water sources.

No basic or supplementary measures under this topic will have an influence on the ecological/chemical status of the coast.

➔ 4. Protected and water rich areas – ground water/ surface water

The measures for ground water deal with the protection against pollution of areas of drinking water extraction.

The measures related to surface water focus on the restoration and maintaince of water rich areas (e.g. wetlands) along the rivers.

No basic or supplementary measures under this topic will have an influence on the ecological/chemical status of the coast.

➔ 5. Quantity of ground water / surface water

Measures for ground water focus on the occurence of quantity problems of ground water in certain areas and the problems related to ground water extraction on the fysical structure of the water system.

The measures related to surface water concern water level management, low water strategies and the construction of extra retention areas.

No basic or supplementary measures under this topic will have an influence on the ecological/chemcial status of the coast.

➔ 6. Inundations

In this group, measures were outlined to deal with problems related to the protection against flooding, including flooding resulting from the changing climate and sea level rise. Most measures relate to inland water systems, but also coastal defence measures were included. The latter influence the “naturalness” of our coast. The coastal defence works protect the inland, but are implemented with the ecological function of it in mind. Therefore, more ‘natural’ measures were used, such as sand suppletion on the beach and foreshore instead of construction of dikes and break-waters. The effect of a suppletion is mostly temporal due to the quick recovery of the benthic community in suppleted sand, in the case of a good match between the suppleted sand and the naturally occuring sand structure (Speybroeck et al., 2008). Nevertheless, coastal defence works have a negative impact on the ecological status of the benthic community due to physical changes in the habitat characteristics (e.g. sedimentology, hard structures).

➔ 7A. Ground water pollution

In this group, measures were taken against pollution from diffuse sources and point sources to protect the ground water against polluted substances (nutrients, insecticides, chemical substances, heavy metals) from human activities.

➔ 7B. Surface water pollution

The biological quality of the surface waters of Flanders improved in recent years, except for the concentration of nitrate and some chemical substances. However, a good ecological status has not yet been reached for a lot of water bodies. In this group, measures were taken to further reduce pollution from diffuse and point sources in the surface waters. Extra measures not related to other European directives (see theme 1) were grouped in following clusters:

- Reduction measures concerning the pollution from industrial sources
- Reduction measures concerning the pollution from the agriculture
- Reduction measures concerning the pollution from other sources (e.g. discharge of pesticides or dangerous waste of households)
- The ongoing restoration of the naturalness of water bodies within the Flemish territory and the increase of the performance of the existing water treatment infrastructure

Measures taken to further reduce the occurrence of anthropogenic substances in inland waters will positively influence the ecological/chemical status of the coast and the status of the benthos. The supplementary measure (7B_054) about the pollution from ship discharges and harbor activities should get more attention in the Flemish plans.

➔ 8. Other damaging effects. Hydromorphology / sediments of water bodies

Concerning hydromorphology, the measures deal with the restoration of water flora, fish fauna and the natural structure of rivers. The Long Term Vision and 2010 Development plan of the Scheldt estuary (www.ontwikkelingsschets2010.nl) is based on the fact that expension of the Scheldt estuary will lead to a better internal processing of organic load, nutrients, pollution and sediments. The aim is that this contributes to a lower supply to the sea and a reduction of the eutrophication in the North Sea.

The topic about sediments of water bodies mainly relates to the issue of dredging and the clean-up of dredged material. Measures were taken to reduce erosion, dredging activities, treatment of polluted sediments and re-use of dredged material.

No basic or supplementary measures under this topic will have an influence on the ecological/chemical status of the coast.

➔ Summary

The measures taken by the Flemish government are mostly focused on an improvement of the water system and on management (protection, reduction of pollution, water use). The measures related to the reduction of the occurrence of nutrients and dangerous substances (heavy metals, chemical substances) will positively influence the ecological status of the coast by reducing the eutrophication and by improving the chemical status.

Detailed information about the programme of measures taken by the Flemish Government can be found at http://www.volvanwater.be/stroomgebiedbeheerplan-schelde/overzicht-download.

3.2.3 Wallonia

The following groups of measures were outlined in the measure programme of the Walloon government (Table 2):

➔ 1. Rehabilitation of used water

Measures taken within this group were related to waste water treatment to reduce the discharge of waste water. These measures are partly based on collective actions (in first instance on large agglomerations, in second instance on smaller ones) and partly on individual rehabilitation projects.

Measures taken within this group will influence the ecological status of the coast (lower eutrophication) and the status of the benthos.

➔ 2. Industry

Measures within this theme focus on prevention, reduction and elimination of pollution by the industry (via water).

- All industries

The measures under this topic focus on licences, taxes and costs for the indurstry to treat their used water.

- IPPC

IPPC applies to heavly polluting industries and agriculture (2008/1/EEG). The measures focus on prevention against pollution.

- Seveso

The directive Seveso (2003/105/EEG) aims to take preventive measures against accidents with dangerous substances and to reduce the consequences for the human population and the environment.

Measures taken within this group will mainly influence the chemical status of the coast (lower chemical pollution).

➔ 3. Agriculture

This group of measures aims to reduce the agricultural pressure on the environment and consistst of 5 sub-groups.

- nutrients

Measures were taken to reduce the nutrient concentrations, especially nitrates (via Nitrate directive translated in the Walloon region in 'le programme de gestion durable de l'Azote en agriculture (PGDA)) by influencing the use of fertilizers by the agricultural sector.

- Erosion

Measures were taken to reduce the erosion at agricultural sites to avoid the run-off of nutrients and pesticides to the rivers.

- Pesticides from agriculture

Measures were taken to reduce the negative impact of pesticides in the rivers by reducing the use of it or by requiring a use in more controlled circumstances.

- Agricultural and environmental measures

Measures are taken, on a voluntairy basis, to reduce the environmental impact of the agricultural activities (e.g. increase of landscape diversity by planting hedges on the agricultural site).

- Exogenous organic materials from the agriculture

This theme concerns the organic by-products which can be valorized in the agricultural sector (urban and industrial mud, compost).

Measures taken within this group will influence mainly the ecological status of the coast (lower eutrophication) and the status of the benthos.

➔ 4. Communities and households

This topic includes measures to reduce the water use by households and communities and to reduce the use of pesiticides and toxic waste-products outside the agricultural sector (communities, public administrations, privately, …).

- Economic use of water
- Non- agricultural pesticides and toxic waste products

Measures taken to reduce the water use will not affecting the ecological/chemical status of the coast, whereas measures against the use of pesticides and toxic-waste products will do so in a positive way.

➔ 5. Protected areas

Under this topic, measures were outlined that protect valuable areas (areas sensitive to nitrate pollution, 50% of the Walloon region), sensitive areas (areas sensitive to nutrient pollution from urban origin), Natura 2000 areas (Habitat- and Bird directive), drink water supply and swim water areas and were all regulated by other European directives. These measures have a local impact and will not contribute to an improvement of the ecological status of the coast.

➔ 6. Water use, inundation, extreme low water level and drainage

Under this topic, all quantitative aspects of the water quality of ground and surface waters related to (extremely) high and low water levels are regulated. These will not result in coastal improvements.

➔ 7. Accidental and historic pollutions

The Walloon region is characterised by a historic past of heavy industry, which created several heavily polluted areas (detailedly mapped). Actions are undertaken to avoid accidental pollutions. Regulations are worked out to regulate the dredging activities and the treatment of dredged sediments.

These measures will help to reduce the outflow of dangerous substances downstream and improve the chemical status of the coast.

➔ 8. Recreational activities

Pressures due to recreation (fishing, water tourism, kajaking, swimming) are regulated in the framework of the promotion of a sustainable use of the Walloon rivers/lakes. These measures have a local impact.

➔ 9. Hydromorphology

- Policy to preserve or restore the naturalness of water bodies.
- Measures to make passages for migrating fish species at water power plants.

These measures will help to restore the ecological function of the rivers and the internal processing of organic load, nutrients, pollution and sediments.

➔ Summary

The measures taken by the Walloon government are mostly focused on waste water treatment and prevention against pollution (nutrients, dangerous substances) and mainly originated from existing regional plans in the framework of other European directives. They will help to improve the ecological status downstream in view of the eutrophication problem and the chemical status of the coastal waters.

Detailed information about the programme of measures taken by the Walloon Government can be found at http://environnement.wallonie.be/directive_eau/pg_menu/pgb.asp?Menu=4.

3.2.4 Brussels capital region

This information is not yet available, but is expected to be added to the website www.bruxellesenvironment.be.

The main measure that is taken in the capital region and that will affect the water quality in the surface water of the Scheldt river basin district is the waste water treatment that started operating in 2007 and that helps to reduce eutrophication.

3.3 France

The Scheldt river basin is partly situated in the Artois-Picardie region of France. The programme of measures taken by the region Artois-Picardie (France) can be summarized as:

- **Housholds rehabilitation**. The aim is to reduce organic material, phosphor, nitrogen and micro-pollutants in the waters by water treatment installations. A large part of the total budget (77%) will be used to accomplish the associated plans.
- **Diffuse pollution**. The aim is to improve the water quality of surface and ground waters by reducing the occurence of nitrogen and all kinds of pesticides, especially in protected areas. Eleven percent of the budget will be spent on this topic.
- **Restoration of the aquatic environment**. The aim is to protect and restore the hydromorphology of the water currents and the habitats important for fauna and flora. Only supplementairy measures were included for 5% of the total budget.
- **Ground water**. The aim is to improve the quality of drinking water by starting treatments against different elements (e.g. iron, ammonium, sulphates, …) and to protect the drinking water extraction sites. One percent of the budget will be spent on this topic.
- **Industry and harbours**. The aim is to obtain a clean industry by prevention, economical use of water, and treatment and reduction of dangerous substances. Measures will also be taken at the harbours of Dunkerque, Boulogne and Calais to reduce their effect on the environment. Six percent of the total budget will be spent on this topic.

The measures taken within these main topics have to accomplish the following 5 main policy orientations and their objectives (Table 2):

➔ Orientation 1: A qualitive policy for the aquatic environment
- Pollution of the aquatic environment with classical pollutants
  Objectives: Reduction of pollutants and especially nitrates of the agricultural sector; measures to reduce the erosion and alternative trajects for rain water. These measures will improve the ecological (tackling euthrophication) and chemical status of the coast.
- Pollution of the aquatic environment with dangerous pollutants
  Objectives: Increase of the knowledge about dangerous pollutants and actions to reduce the outlet of toxic substances. These measures will meanly influence the chemical status of the coast.
- Protection of the drinking water reserve

➔ Orientation 2: A quantitive policy for the aquatic environment
- A policy for an economic use of water
- Inundations
  Objectives: Reducing the damage of flooding, protection works against flooding, reducing the drainage from cities and countrysides, preparation against the risks of sea level rise.

➔ Orientation 3: The management and protection of the aquatic environment
- Protection and recovery of the quality of the coastal environment. Most of the outlined measures below will primarily influence the ecological status of the French coast.
  - Define the vulnerability of the environment in de 'zone conchylicole' (area for the cultivation of bivalves)
  - Limit the microbiological risk in the coastal zone
  - Integrate the functional dynamics in the coastal area in the coastal policy
  - Intensively control the environmental pollution originating from the harbours and ships
  - Issue measures to reduce the eutrophication problem in the marine environment
  - Protect the coastal environment against local pressures
- Morphology, functionality and ecological continuity of the surface waters
  Objectives: Protection of the functionality of the aquatic environment, protection and recovery of the water dynamics in the systems and a good ecological policy against fishing.
- Protection of natural wetlands by putting a stop to their disappearance and degradation
- Ecological functionality and biodiversity
- Maintanance of the high ecological potential in natural aquatic areas

➔ Orientation 4: The treatment of historic pollution
- The management of polluted deposits (dredging) and historic pollutions, which will help to improve the chemical status of the coast.
- Improving the knowledge of the impact of polluted sites on the environment

➔ Orientation 5: More innovative policy to collectively manage our community
- A good organization and synchronization of the local and global plans for water policy
- Cultivating and informing the community

➔ Summary

The measures taken by the Artois-Picardia government are mainly focused on waste water treatment and the reduction of pollutant concentrations (nutrients, dangerous substances). These measures are expected to have an effect downstream. Measures focused on the marine environment were included in the plans, and they will have a positive influence on the ecological status of the French coast. The measures to reduce the coastal eutrophication will also help to reduce this problem in Belgian coastal waters.

Detailed information about the programme of measures taken by the Artois-Picardie region in France can be found at http://www.eau-artois-picardie.fr.

3.4 The Netherlands

The measure programme of the WFD builds on the current water policy of the Netherlands, where the WFD programme can be seen as the final piece of the water quality policy. The WFD measure programme of the Netherlands is outlined as follows (Table 2):

➔ 1. Measures taken based on the European water protection legislation

A lot of measures were taken in the context of other European directives and only the directives which mainly influence the ecological/chemical status downstream were outlined in more detail.

- Bird- and Habitat directive (79/409/EEG and 92/43/EEG): A lot of areas in the Dutch Scheldt river basin were protected under this directive, including the Voordelta (southern part of Dutch coast) and the Westerscheldt. This will lead to an ecological management of neighbouring areas.
- The Directive for the treatment of urban sewage (91/271/EEG) has lead in the Netherlands to a good connection between the households and the sewage system. Due to the eutrophication problems along the coast, the minimum percentage of extraction of nitrogen and phosphor in the water treatment installations is increased to 75% for the entire country.
- The nitrate directive (91/676/EEG) has the aim to reduce the organic emission from the agricultural sector; the measures were primarly focused on a better use of the manure and a creation of buffer areas nearby ecologically sensitive rivers.
- The directive for the discharge of dangerous substances (2006/11/EG) has the aim to avoid and reduce the pollution of the water with certain dangerous substances.
- The directive of biocides (98/8/EG) has the aim to reduce the hazard of these substances for the environment by taking measures to determine standards for the substances and to reduce the use of the biocides.
- Other directives outlined in the Dutch report help to improve the overall ecological status of the waters, but not directly the coastal waters.

➔ 2. Measures to regulate the recovery of the costs of water use

The water policy of the Netherlands is already based on this principle and will be updated and continued.

➔ 3. Measures to achieve a sustainable and efficient water use.

A lot of measures were formulated to fulfill this aim and can be grouped in sustainable water quantity policy, the regulation of ground water extraction, taxes on ground and drinking water and raising awareness of water use at a community level.

➔ 4. Measures to protect drinking water

Measures were taken to protect the quality of drinking water and to protect the drinking water extraction areas.

➔ 5. Measures for extraction and congestion of water

Licences are needed to extract or congest surface water or groundwater.

➔ 6. Measures for artificial ground water suppletions

Licences are needed for direct infiltrations of surface water to the ground water to avoid pollution.

➔ 7. Measures for point sources

It is forbidden to discharge sewage into groundwater and licences are needed to discharge polluted and dangerous substances into surface waters. Furtehermore, highly polluted soils and ground water areas will be cleaned up. These measures will help to improve the chemical status downstream.

➔ 8. Measures for diffuse sources

Measures related to the present problem substances by reducing the emission (PAK, copper, zink, pesticides, biocides, phosphate, nitrate). These measures will help to improve the chemical status downstream.

➔ 9. Measures regulating the water current and hydromorphology.

Measures related to improve the 'naturellness' and ecological functioning of rivers and water courses.

➔ 10. Measures for regulating direct discharge of substances into groundwater

➔ 11. Measures regarding priority substances

See the directives under point 1 for most of the measures - mostly focused on the regulation of licences for use of these substances.

➔ 12. Measures to avoid accidental events

The aim of the measures taken under this topic is to avoid or reduce the impact of accidental pollutions.

➔ 13. Supplementary measures

Supplementary measures were taken by some sub-regions in the Scheldt river basin of the Netherlands to reach the WFD aim. They can be summarized as improvements to avoid pollution of point sources, clean-up of polluted dredged substances, creation of natural river shores, fish passages nearby sluices and the reduction of the occurrence of barriers along the rivers.

➔ 14. Extra measures

Following topics were suggested: to treat the reduction of the 'upstream' impact on the Dutch waters on an international level, to make improvements to the WFD monitoring programme, to take research measures.

➔ 15. Measures regarding marine waters

The emission reduction measures 'upstream' must lead to improvements of the ecological status in the marine waters. Discussion and more research is needed on the threat of polluted chemical substances to the marine environment, but negative consequences were observed at present. In the Netherlands, a supplementary reduction of 15-20% of nutrients (especially nitrogen) compared to 2000-2006 will be the target. The developments in the neigbouring countries are very important to obtain this aim.

➔ Summary

Most measures in the Netherlands were implemented in their current water policy. The supplementary measures of the WFD focus on hydromorphology works (natural shores, fish passages, natural current) and on both point sources and diffuse sources. The measures will attribute to improvements in the Dutch waters towards 2027, but their effects will strongly depend on the developments in the countries upstream.

Detailed information about the programme of measures taken by the Netherlands can be found at http://www.kaderrichtlijnwater.nl/publicaties.

3.5 Summary of the measures

It can be concluded that there is a high similarity between the measure programmes of the different regions and countries, which focus on the same main topics (reduction of pollutants and restoration of natural hydrodynamics) (Table 2). The measure programmes were mainly based on existing national/regional plans, in turn based on other European directives. The involved countries and regions regard the WFD as the umbrella for their water policy (the aim of the WFD). The outlined measure programmes were quite abstract, but the projects under each measure type were defined on a local scale for some regions/countries. The measure programme of Flanders mainly focuses on protection against ground water and surface water pollution from households, industry and agriculture. This is mostly the same for the other regions/countries, except in France and the Walloon region, in which strong investments in waste water treatment are planned. The Netherlands mainly focus on hydrological works, next to the protection against pollution (already implemented in their current water policy) to improve the ecological/chemical status of their waters. They mostly depend on upstream measures to reduce the chemical pollution (nutrients, dangerous substances). The Belgian Federal government has little authority concerning water policy so it depends on regional actions to improve the ecological/chemical status of the coast. It would be advisable to increase the consultancy with the regions and to stimulate them to make increasing efforts to reduce the pollution in marine waters

Box 3. Eutrophication problem

The solution for the eutrophication problem is different for fresh and marine waters. In fresh water, the phosphor concentration has to be primarily reduced. In marine waters, the nitrogen concentration is more important. Recently, the phosphor concentration has undergone a stronger reduction than nitrogen in downstream waters. This causes instability in the N/P ratio, which is responsible for the *Phaeocystis* dominance in the plankton in our coastal waters (Lancelot et al., 2007). To tackle this problem, the future management of nutrient emmission has to focus on decreasing nitrogen discharge. For the moment, the application of the current measures will lead to a further reduction of 15% of the total nitrogen and 50% of the total phosphor at the Dutch-Belgian border of the Scheldt (PEGASE model). The Netherlands estimate that a reduction of 15-20% of nitrogen is needed to obtain a good ecological status based on phytoplankton. For the Belgian coast, estimates were made that a reduction of more than 50% of nitrogen and phosphorus (up to 90%) is needed to solve the eutrophication (Lacroix et al., 2006). This information shows that, based on the current measures, the eutrophication problem in coastal waters will not be solved.

(e.g. harbor policy/control; fishery).

As outlined, the current measures taken by the regions/countries mainly focused on solving local environmental problems, except that the measures for reduction of pollutants (nutrients, dangerous substances) will have an influence on the ecological/chemical status downstream. However, no ambition levels for the percentage of reductions of these pollutants downstream were included in the plans. Most regions/countries have the aim to reduce their pollutants to the level corresponding with a good ecological and chemical status in their local waters. This policy has two main results: (1) the solutions for certain problems in inland waters and marine waters were sometimes different, as illustrated by the eutrophication problem (box 3) and (2) it is difficult to translate local reduction values to what can be expected downstream (model type dependency). To solve these problems, the plans were grouped on a river basin scale and the consultancy structures were created to discuss them (e.g. Scheldt river basin committee). This proces is in progress, but for the moment the downstream regions depend on the goodwill of the upstream regions to improve the ecological status of their waters. Therefore, it is difficult for the authority of a downstream region (e.g. Belgian Federal Government) to evaluate the effects of the measures on the ecological status of their water bodies. Consequently, it is advisable to further intensify the water problem discussion on a bigger scale, so that the downstream problems can also be tackled byt the upstream measures.

No specific measures for coastal waters were taken by any region/country, except for France All hopes to improve the ecological status depends on their upstream measures, so improvements cannot always guaranteed (see box 3).

The discussion section will describe and discuss the actions/adivces that can be taken/given by/to the Federal Government.

Table 2. Overview of the measure groups and their effect on the ecological or chemical status of the coastal waters of Belgium by the Federal state of Belgium, the Flemich Governement, Walloon Government, France and the Netherlands. The measure groups for which is nothing assigned by a certain region or country, means that they not directly mention it in their River Basin Management Plan. E: effect on ecological quality status; C: effect on chemical quality status

Measure group	E/C	Federal	Flanders	Wallonia	France	The Netherlands
➔ European water protection legislation						
• Bird- and habitat directive (79/409/EEG, 92/43/EEG)	E	+ Will take time, and effect will depend on the policy	- Local	0 Local	0/+	0/+
• the nitrate directive (91/676/EEG)	E/C		+	+	+	+
• the directive concerning the treatment of urban sewage	E/C		+	+	+	+
• European directive on the assessment of public and private projects on the environment (97/11/EG)		0				
• European directive for introducing plant protection products on the market (91/414/EEG)	C	+	+			+
• The daughter directive of the European dangerous substances directive (76/464/EEG)	C	+				+
• European shellfish waters directive (2006/113/EG)		0			0	
➔ Sustainable water use			0	0	0	0
➔ Protection of drink water areas			0	0	0	0
➔ Hydromorphology	E		0/+	0/+	0/+	0/+

Measure group	E/C	Federal	Flanders	Wallonia	France	The Netherlands
➔ Measures for point discharges diffuse sources and other activities influencing the surface water state.						
• Prohibition of direct discharges	C	+				+
• Measures for pollution sources related to industry	C		+	+	+	+
• Measures for pollution sources related to agriculture	E/C		+	+	+	+
• Dumping of dredged material	E	- Local impact				
➔ Groundwater measures			0	0	0	0
➔ Measures related to priority substances	C	+	+	+	+	+
➔ Measures to avoid or reduce the effect of accidental and operational pollution; historic pollutions	C	0/+ Negative impact in case of a pollution event		0/+	0/+	0/+
➔ Inundations			0 Coastal defence works: --	0	0	0
➔ Recreational activities				0		
➔ Measures to regulate the recovery of the cost of water use			0			0

Measure group	E/C	Federal	Flanders	Wallonia	France	The Netherlands
➔ Supplementary measures to reach the environmental objective of the WFD	E/C	Integrated coastal zone management; fishing for litter; research				avoiding pollution of point sources, clean-up of polluted dredged substances, creation of natural river shores and reduce barriers, fish passages nearby sluices
➔ Measures to avoid increase of the pollution of marine waters	E	- No measures were taken to avoid introduction of invasive species			+ Influencing primarily the ecological status of the French coast	0 No extra measures were outlined under this topic
➔ Climate check	E	0/+				

4 Scientific information

4.1 Present ecological status and reference conditions of the benthos in the Belgian coastal zone

The ecological status of benthos is determined using the Benthos Ecosystem Quality Index (BEQI) (Van Hoey et al., 2007; Ysebaert et al, in prep). The BEQI evaluates at three levels: ecosystem, habitat and community. Several functional, structural and biological parameters are used and integrated into one index (Box 4). The BEQI has the aim to evaluate the changes of the current condition in relation to the predefined reference conditions for each parameter.

To evaluate the ecological status of the benthos within the different habitats in relation to the anthropogenic gradient of the coast (increasing negative influence of the Scheldt from west to east), the water body ‘Belgian coast’ is devided into three zones (Figure 2): (1) a western zone, from the French border to Middelkerke, including the Yser estuary; (2) a central zone, from Middelkerke to De Haan, including the harbour of Ostend; and (3) an eastern zone, from De Haan towards the Scheldt estuary, including the harbours of Blankenberge and Zeebrugge.

The habitat typology for the Belgian coast is based on biological community analyses (Degraer *et al.*, 2003, Van Hoey *et al.*, 2004, Derous *et al.*, 2007). Four main communities/habitats for the Belgian coast were defined: (1) the *Abra alba* – *Mysella bidentata* community characterised by high densities and diversity and mostly found in fine muddy sands (*Abra alba* community); (2) the *Nephtys cirrosa* community characterised by very low densities and diversity and found in well-sorted sandy sediments (*Nephtys cirrosa* community); (3) the *Ophelia limacina* – *Glycera lapidum* community characterised by very low densities and diversity and found in coarse sandy sediments (*Ophelia limacina* community); (4) the *Macoma balthica* community characterised by low densities and diversity and found in muddy sediments (*Macoma balthica* community). Based on biological and physical data, different communities were found to be of major importance in the three zones. For zone 1, the *Abra alba* habitat*,* the *Nephtys cirrosa* habitat *and* the *Macoma balthica* habitat were evaluated; for zone 2, the *Abra alba* habitat and the *Macoma balthica* habitat were evaluated, and for zone 3, the *Macoma balthica* habitat was evaluated.

4.1.1 Reference conditions

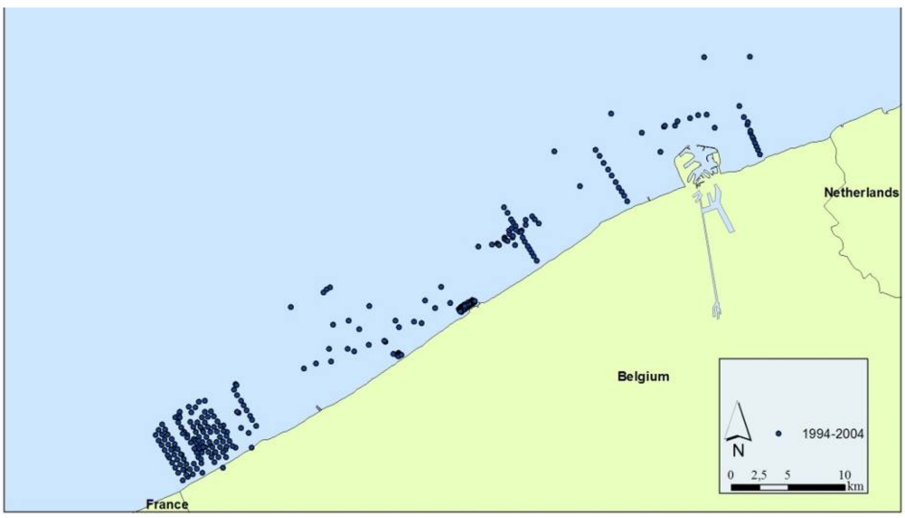

Figure 1. The spatial distribution of the samples in the reference period 1994- 2004.

Box 4. Benthic Ecosystem Quality Index (BEQI) (Ysebaert et al., submitted)

The BEQI consists of three assessment levels, each of which consists of one or more parameters. A detailed description of the BEQI can be found in Ysebaert et al. (subm.), and this can be summarized as follows:

Level 1 – At the ecosystem level, the BEQI uses the relationship between macrobenthic biomass (B) and system productivity (P, sum of fytoplankton and microfyto-benthos), as was demonstrated by Herman et al. (1999) based on a series of estuarine and coastal systems worldwide. This relation implies that for these shallow, well mixed, systems between 5% and 25% of the annual primary production (pelagic and benthic) is consumed by macrobenthos. The rest of the production is either consumed by pelagic grazers or directly incorporated into the microbial food web after decaying of the algal bloom. A B:P ratio of 1:10 is used as the reference ratio between the system primary production and the macrobenthic biomass (Escaravage et al. 2004). This ratio may represent a state of equilibrium where the sum of pelagic and benthic primary production is adequately matched by the biomass of grazers that are present in the system (i.e. macrobenthos and zooplankton). Deviations from this relation could point at unbalanced ecosystem functioning (Ysebaert et al., in prep) and were scaled according to the WFD definitions (see further).

Level 2 – At the second level the BEQI considers the spatial distribution of habitats within an ecosystem. At this level one addresses the diversity of habitat types, and compares the availability and spatial organisation of these types to an expected reference state, based on the physical and geomorphological constraints of the system. The term habitat refers to large, broad scale geomorphological structures in these ecosystems, easily quantified from remote sensing and sounding techniques, such as sand flats, mudflats, shallow subtidal, channel. When applying this indicator to the WFD, BEQI uses currently the surface area (spatial extent) of habitats as criterion at this level. The BEQI also includes eco-elements, these are habitats constituted of species that form conspicuous biogenic structures, in coastal and estuarine soft-sediment systems typically formed by e.g. mussel beds, oyster reefs. The current status can be evaluated against a certain historical reference period, expert judgment or against the management objectives for a certain water body, evaluating as such the physical changes in the water body due to human activities: habitat loss due to land reclamation or infrastructural works, morphological changes due to dredging, etc. The deviations from the reference were scaled according to the WFD definitions (see further).

Level 3 – At the third level the BEQI analyses and evaluates the benthic macrofauna community per habitat or ecotope. The term ecotope is used from a landscape perspective. Ecotopes are ecologically-distinct landscape features that are useful for stratifying estuarine landscapes for the measurement and mapping of landscape structure, function and for the measurement of spatial changes and the ecological potentials of the system. In the Netherlands a hierarchical ecotope classification has been worked out for brackish and marine waters. It uses salinity, depth or tidal elevation, hydrodynamics and sediment characteristics to define benthic ecotopes (Bouma et al. 2005, Ysebaert et al., in prep). Threshold values defined for each parameter delimit condition classes wherein a characteristic benthic community is expected to occur. The BEQI level 3 uses four biological parameters: number of species, total density (ind.m^{-2}), total biomass (g AFDW.m^{-2}), and similarity (Bray-Curtis similarity based on 4^{th} root transformed density data). The similarity index compares the assessed species composition (species and their densities) with a reference species composition. Each parameter gives different information about the structure and functioning of the benthic community (Ysebaert et al. subm.).

The BEQI evaluates the benthic community at the level of a habitat or ecotope, rather than the evaluation of a single sample. This requires a certain amount of reference and assessment samples and sampling area per habitat or ecotope, and this allows the incorporation of natural variability (spatial and temporal). A power analysis is used to detect the minimal number of samples or sampling surface required given an acceptable level of confidence.

The BEQI takes into account the total sampling surface within a certain habitat or ecotope, as the parameter results will strongly depend on the sediment surface sampled (Ysebaert et al. , in prep). Therefore, the expected reference values for the BEQI parameters are calculated per habitat or ecotope from permutations executed over increased sampling surfaces. An algorithm was used that computed rarefaction curves using a random resampling procedure with replacement (i.e. bootstrapping, using 2000 random samples). This allows estimating, for any given sampling surface, the reference value that can be expected, which then can be compared with a similar sampling surface used to evaluate the current ecological status. For the parameter number of species and similiarity a one-sided evaluation approach (only values lower than the reference are evaluated in the high-bad gradient) is used, whereas for the parameters density and biomass a two-sided evaluation approach (values lower or higher than the reference are evaluated in the high-bad gradient) is used. Additionally, the BEQI also produces a list of species that are responsible for observed deviations from the reference state (a list of species which contributing most to the dissimilarity between reference and assessment: SIMPER analysis), which give additional insight into how the current state has changed. This is done for the parameters density, biomass and similarity.

Ecological quality status classes – For each parameter at the three levels, reference values were determined for each ecological status class boundary of the WFD: high, > 0.8; good, 0.6-0.8, moderate, 0.4-0.6; poor, 0.2-0.4; bad, ≤ 0.2 (Figure 1). For level 1 and 2, a reference value is determined for the high/good boundary and the values for the other WFD class boundaries were determined by equal scaling of this high/good reference value. At level 3, the reference value of the good/moderate boundary is determined based on the 5^{th} percentile (number of species, similarity) or on the 2.5^{th} and 97.5^{th} percentile (density, biomass) out of the permutation distribution of each parameter (Ysebaert et al. subm.). The moderate/poor and poor/bad reference value were determined by equal scaling (respectively 2/3 and 1/3 of the good/moderate reference value), whereas the median value (number of species, similarity) or the 25^{th} and 75^{th} percentile (density, biomass) out of the permutation distribution was used as the reference value of the high/good boundary.

Overall BEQI score – For the WFD, the different levels of the BEQI need to be summarized and integrated into one overall EQR and ecological status class. In the BEQI method priority is given to both transparency and simplicity. Each step of the integration remains visible and interpretable. At the level of the ecosystem, one parameter value is obtained, but at the other two levels more parameters are calculated and the overall EQR value of that level is obtained by averaging. Within level 3, first the ecotope is evaluated based on the average outcome for the four biological parameters, after which the outcomes of the different ecotopes are averaged to get an average estimate at level 3.

The WFD prescribes that the reference conditions should be determined prior to, or spatially outside the influence of human activities, a precondition that cannot be fulfilled in our region. Consequently, the reference conditions were pragmatically defined in such a way that the reference data reflect the temporal and spatial variability of the benthos as good as possible, based on existing data.

The benthos data gathered for the Belgian coast (< 6 nautical miles from the coastline) for determining the reference conditions originate from long-term monitoring at fixed stations and grid sampling in the framework of different projects, and go back to 1976 (1224 samples). Only data from summer-autumn were selected from the dataset because the WFD monitoring occurs in autumn and because seasonality differences between reference data and assessment data should be excluded. The sampling intensity along the Belgian coast increased in time. Prior to 1994, mostly fixed stations were sampled (except in 1977). In recent years, more campaigns with an increased spatial coverage were included. The lowest spatial coverage was found in the 80's, followed by the 70's. In the 90's, there was a very good spatial coverage of the samples along the west coast, but almost none at the east coast. From 2000 onwards, there was a wider spatial distribution of the samples along the entire Belgian coast, but with a focus on the central part and the east coast. Most of those samples were taken in 2006, which is very recent.

The ideal period to select as reference appeared to be 1994 – 2004, with a 10 year temporal coverage and a very good spatial distribution along the Belgian coast (figure 1). All reference samples were linked to the three habitat types that were found in the Belgian coastal zone: the *Abra alba, Nephtys cirrosa* and *Macoma balthica* habitat, each containing samples typical for the community *sensu strictu*, but also samples that form the transition to other habitat types. In such way, the temporal and spatial variability within a certain habitat is covered by the selected reference data.

4.1.2 Evaluation

The evaluation of the ecological status of the benthos is based on the monitoring data collected in autumn 2007. Based on a random stratified sampling strategy, 9 groups (each 0.6 m²) of 15 Van Veen samples were taken along the Belgian coastline (Figure 2) representing the different habitats in the three zones.

The ecological status assessment of the benthos of the Belgian coast is based on level 1 and 3 of the BEQI. Level 2, which evaluates changes in habitat areas is not included, because no information of past and current habitat areas is available.

Level 1 – Euthrophication problems in the coastal waters cause massive blooms of *Phaeocystis* every spring, a phenomenon that intensified over the last 20 years due to changes in the nitrogen/phosphorus balance (Lancelot et al., 2007). Chlorophyll concentrations in recent years are higher than the threshold values defined by OSPAR. This indicates that the phytoplankton in the coastal waters does not correspond with the reference state. Direct primary production measurements for the assessment year (2007) were not available. Primary production estimates for the Belgian and Dutch coast resulted in values of 250-440 g C/m² yr in the nearshore (Bot & Colijn, 1996). Model primary production estimates for the Belgian coast showed an increase from the 1950's to 1980s (around 125 g C/ m² yr) and early 1990s (max of 300 gC/m²yr), with a decrease towards 2000 (around 200 g C/ m² yr) (Lancelot et al., 2007). The average benthic biomass value (AFDW/m²) of the WFD monitoring stations is 5.9 g/m². Based on these values, it can be concluded that the relationship between benthic biomass and system primary production is unbalanced and lower than 1/10. This means that the benthos in the Belgian coast (< 1 nautical mile from the coastline) does not consume the available phytoplankton as expected (ideally 10% of phytoplankton) (Herman et al., 1999). Based on these observations and expert judgment, it can be stated that the relation between system primary production and macrobenthic biomass is unbalanced; a phenomenon that needs further investigations. Corresponding with the precautionary principle, the EQR was set on 0.6 (good-moderate boundary), because it can not be determined if this level is in a good or moderate status and not to affect the end score when the other BEQI scores were averaged.

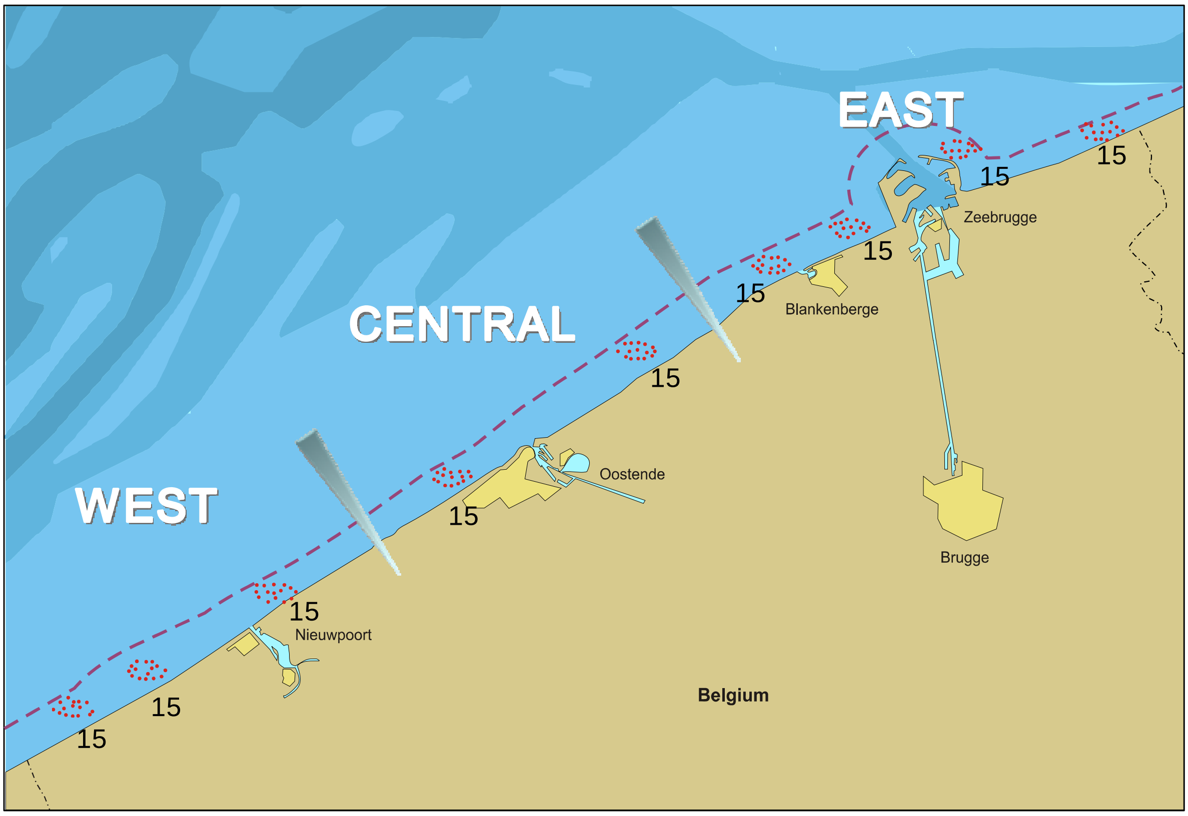

Figure 2. Position of the 9 sampling locations, with indication of the three zones at the Belgian Coast.

Level 3 (Table 3) – At level 3, the parameter biomass was not evaluated due to the lack of biomass reference data. In zone 1 of the Belgian coast, the *Nephtys cirrosa* and *Macoma balthica* habitat showed a good status, due to a good or high status of the benthic parameters density and number of species (Table 3; Figure 3). The *Abra alba* habitat showed a moderate status. In zone 2, the *Abra alba* habitat is evaluated as good, but caution is needed during interpretation of the results because too few samples were used in the assessment to get a representative assessment. The *Macoma balthica* habitat displays a moderate status, due to the low densities and number of species compared to the reference. The *Macoma balthica* habitat in zone 3 displays a moderate status, due to the moderate status of the three benthic parameters. The overall score at level 3 for the benthos at the Belgian coast, by averaging the scores per habitat (*Abra alba*: 0.609; *Macoma balthica*: 0.533; *Nephtys cirrosa*: 0.750), was 0.631, which means a good status.

Overall score - When combining the different levels, the EQR score for the Belgian coast was 0.62, which means a good status for the Belgian coast for the quality element benthos. However, a lower ecological status was found for some habitats or areas. This indicates that there were some pressures on the benthos in the coastal area, which prevented the maintenance/development of a ‘healthy’ benthic ecosystem.

Table 3. The assessment values, reference boundary values and EQR score for each parameter of level 3 of the BEQI for the different habitats in each zone.

	parameter	Assessment		Reference boundary values										EQR	
Habitats		surface	value	Poor min	Mod min	Good min	High min	Median	High max	Good max	Mod max	Poor max	Max	score	status
zone 1	density	0.92	2949	796	1591	2387	4199	5573	7708	13010	17347	21683	43366	0.672	good
Abra alba	similarity	0.92	0.57	0.22	0.44	0.66	0.74							0.521	moderate
2007	species	0.92	56	19	39	58	70						156	0.579	moderate
	average of parameters													0.591	moderate
zone 1	density	1.47	333	64	128	192	266	320	392	586	781	977	1953	0.962	high
Nephtys cirrosa	similarity	1.47	0.54	0.20	0.41	0.61	0.69							0.531	moderate
2007	species	1.47	40	11	22	33	42						92	0.756	good
	average of parameters													0.750	good
zone 1	density	2.13	472	97	194	291	522	726	976	1536	2048	2559	5119	0.764	good
Macoma balthica	similarity	2.13	0.57	0.22	0.43	0.65	0.74							0.529	moderate
2007	species	2.13	42	14	27	41	49						91	0.625	good
	average of parameters													0.639	good
zone 2	density	0.62	4610	621	1242	1863	3875	5598	7841	15345	20460	25575	51150	0.892	high
Abra alba	similarity	0.62	0.47	0.19	0.39	0.58	0.7							0.490	moderate
2007	species	0.62	40	16	32	48	61						156	0.500	moderate
	average of parameters													0.627	good
zone 2	density	1.83	167	92	185	277	496	726	998	1657	2209	2761	5523	0.369	poor
Macoma balthica	similarity	1.83	0.51	0.21	0.42	0.63	0.72							0.488	moderate
2007	species	1.83	31	13	25	38	47						91	0.489	moderate
	average of parameters													0.449	moderate
zone 3	density	6.09	410	143	286	429	635	765	902	1228	1638	2047	4094	0.577	moderate
Macoma balthica	similarity	6.09	0.63	0.27	0.55	0.82	0.86							0.458	moderate
2007	species	6.09	51	20	41	61	68						91	0.502	moderate
	average of parameters													0.512	moderate

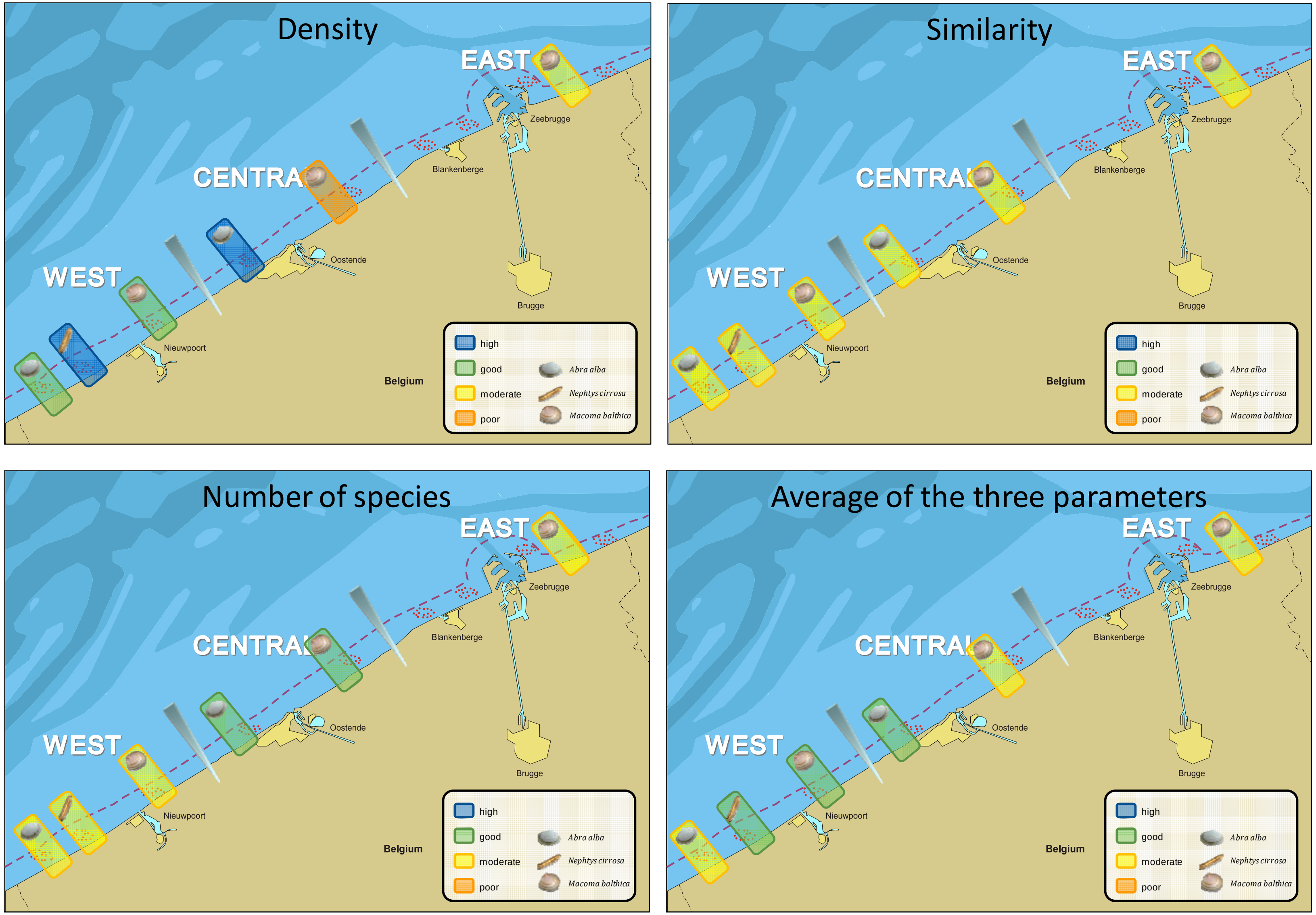

Figure 3. Visualisation of the ecological status per parameter and overall status at level 3 for the Belgian Coast.

4.2 Relation between benthic parameters and environmental conditions

In order to scientifically evaluate the future ecological status of the benthos of the Belgian coast, it is important to summarize and further explore the linking between the benthic parameters (density, biomass, species richness and diversity) and environmental parameters. Given the aims of the present study, anthropogenically influenced environmental parameters (nutrients, organic matter, oxygen, turbidity) and parameters with an anthropogenic origin (heavy metals, chemical contaminants) were of great interest. A focus on these parameters enables the evaluation of the effects of any reduced anthropogenic influences on the benthic characteristics. It is known that mainly sedimentological parameters determine the spatial distribution of the benthos,whereas other variables have a less predictive influence (e.g. Chlorophyll A, nutrients, organic carbon content) (Snelgrove & Buttman, 1994; Degraer et al., 2002; Van Hoey et al., 2004; Willems et al., 2008). Additionally, a lot of variables influence each other. The nutrient concentration, for example, determines the phytoplankton variables, which in turn influence the organic carbon content in seafloor sediments.

4.2.1 Nutrients (nitrogen, phosphor)

The Belgian coastal waters are enriched with nutrients delivered by rivers (Scheldt, Ijzer) and canals, coastal tributaries, atmospheric deposition, and advection from adjacent areas (southwesterly Atlantic waters enriched by the rivers Seine, Somme, Authie and Canche, and Rhine) (Lacroix et al., 2004). Mainly the areas in front of an estuary are characterized by high sedimentation rates of fine-grained sediments and high benthic mineralization rates; the local macrobenthic communities are mainly dominated by deposit feeders (Wijsman et al., 1999).

River nutrient loads are largely influenced by human activity and depend on the land use and agriculture practices, population density, industrialization and waste water treatment management. Nutrient concentrations exported to the marine waters increased strongly towards the 1980’s, whereafter the situation became more or less stable and even tended to decrease in recent years (Rousseau et al., 2006). Of the different nutrients, the concentrations of phosphor were declining stronger than those of nitrogen, which causes instability in the N/P balance and triggers harmful algal blooms (*Phaeocystis*) (Lancelot et al., 2007). The nutrient loads have a direct effect on the phytoplankton composition, growth and production and an indirect influence on the benthos due to the benthic-pelagic coupling. When the nutrient loads decrease, the primary production decreases simultaneously, which indirectly leads to a decrease in food availability for other species (the benthic deposition decreases). In the study of Aertebjerg et al. (2003), it is stated that the decrease in zoobenthos stocks in 1998-2001 was possibly the result of reduced N-nutrient concentrations and reduced diatom abundance. In the Waddensea (Phillipaert et al., 2007; Van Hoey et al., 2007), it was observed that a decrease in nutrient load does not directly result in a decrease in benthic biomass. These different benthic responses in those areas can be related to the fact that there are differences in retention capacities of nutrients in the systems and that the response also depends on benthic primary production.

It can be concluded that decreases in nutrient loads primarily influence the phytoplankton production and composition, which indirectly influence the benthic ecosystem. The response of the benthic system can be variable and depends on local ecosystem characteristics.

4.2.2 Plankton variables (chlorophyll, primary production)

The plankton variables chlorophyll and primary production are commonly used as a proxy for the food availability for higher trophic levels. Changes in these parameters lead to changes in the benthos (benthos-pelagic coupling) (Van Hoey, 1999; Vanaverbeke et al., 2007). On the long run, the benthic density and biomass decrease with decreasing primary production.

Nutrient enrichment has an effect on the relative abundance of the spring diatoms, on *Phaeocystis* colonies and on summer diatoms (Lancelot et al., 2007). The long term evolution of R-MIRO spring maxima of bulk phytoplankton (Chl a), spring and summer diatoms and *Phaeocystis* colony biomass are analyzed in comparison with concomitant changes in nutrient enrichment. Clearly, phytoplankton biomass increased in response to DIN and DIP enrichment up till 1985 when a Chl a maximum three times higher than in 1950 is simulated. After 1985, model results show significant decreases (30% in 15 years) of total biomass which can be related to DIP decrease. Curiously, the maximal biomass reached by spring diatoms seems little modified by increased nutrient enrichment which affects both *Phaeocystis* colonies and summer diatoms. After 1960, the maximum biomass of summer diatoms and *Phaeocystis* colonies increase in parallel and both reach their maximum in 1985 when DIN and DIP enrichment is maximal. Then, summer diatom and *Phaeocystis* colony maxima decrease in parallel, apparently correlated with the simulated DIP decrease. The decrease of *Phaeocystis* colonies is of little significance, i.e. 30% between 1985 and 2000. Altogether, this suggests that a well-balanced DIN and DIP enrichment is beneficial to *Phaeocystis* colonies and summer diatoms while spring diatoms remain unaffected; the imbalanced decreases of DIP and DIN in favour of elevated N:P ratios (> 25) limit the growth of summer diatoms more than *Phaeocystis* colonies that are maintained at high biomass.

These changes in phytoplankton characteristics undoubtedly influence the benthic fauna characteristics, due to the fact that the consumable part of the phytoplankton decreases stronger than the unconsumable part (*Phaeocystis* colonies). *Phaeocystis* can be mineralised in the benthic environment but more research is needed to quantify the amount of *Phaeocystis* that can be assimilated (Vanaverbeke et al., 2009). The changes in phytoplankton can lead to an intensified eutrophication problem in some areas, leading to increased primary production, changes in algal composition (Gieskes & Kraay, 1977; Cadée and Hegeman, 1991; Billen et al., 1999), blooms of toxic algae (Billen et al., 1999), decreased oxygen concentrations (Gerlach, 1984) and a reduction in the macrobenthos (e.g. in the German Bight: Rachor 1980). The effect of a productivity difference on benthic diversity is not uniform and depends on the area and benthic community type (Witman et al., 2008).

4.2.3 Organic carbon content of the seafloor

Pearson and Rosenberg (1978) described a general model of effects of organic enrichment on benthic organisms. According to this model, the first detectable change is a slow increase in number of species, followed by an increase in biomass and subsequently an increase in abundance at relatively high organic carbon content (Figure 4). At higher values of organic load, species diversity, biomass and abundance decrease dramatically since anaerobiosis installs. A change in community structure will follow favouring suspension and burrowing detritus feeders (Aertebjerg et al., 2003), while in areas with high organic load opportunistic species will be favoured. While organic matter in sediments is an important source of food for benthic fauna, an overabundance can cause reductions in species richness, abundance, and biomass due to oxygen depletion and buildup of toxic by-products (ammonia and sulphide) associated with the breakdown of these materials (Hyland et al., 2005). Moreover, increasing organic content of sediment is often accompanied by other chemical stressors co-varying with sediment particle size. Coastal waters all over the world were influenced by high organic loads from rivers. Therefore, the area nearest these rivers were characterised by low species numbers, density and biomass values, whereas they increase with increasing distance from the river source (Grizzle & Penneman, 1991).

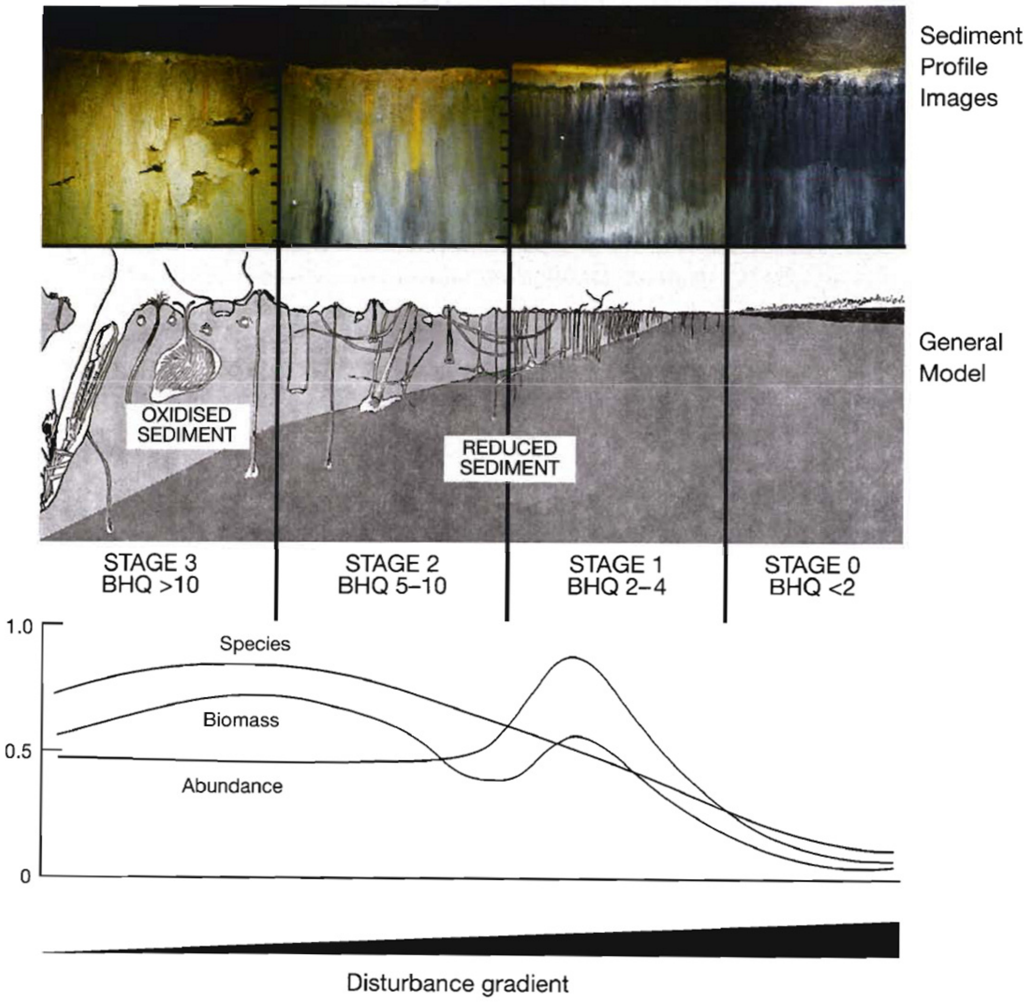

Fig. 1. Distribution of benthic infaunal successional stages along gradient of increasing environmental disturbance (from left to right) (after Pearson & Rosenberg 1978), and associated benthic-habitat quality (BHQ) index (Nilsson & Rosenberg 1997). Sediment-profile images assigned to successional stage are shown above the general model (colours digitally enhanced); oxidised sediment is rust-brown, and reduced sediment grey or black. Bottom graph illustrates generalised changes in species, abundance, and biomass (after Pearson & Rosenberg 1978)

Figure 4. Pearson & Rosenberg model (Rosenberg et al, 2001)

4.2.4 Turbidity

In many coastal plain estuaries, light attenuation confines the photic zone to a fraction of the water column such that light availability is the limiting factor on phytoplankton productivity despite high nutrient levels in many cases (Parr et al., 1997). However, high turbidity levels do not necessarily preclude high phytoplankton standing crops. Where rapid and complete mixing of the water column allows algal cells to have some exposure to light at the surface, phytoplankton biomass can increase where turbidity is high (Parr et al., 1997). Turbidity caused by resuspension of sediments results in associated effects of increased oxygen demand, release of nutrients and potentially toxic substances.

The effects of high turbidity or suspended solids on the benthos can occur through the concentration of particles in suspension (especially in the boundary layer between sediments and the water column) and through the deposition of particles onto sediments or hard surfaces. Filter-feeding organisms entrain particles from the water column using a variety of feeding appendages. An increase in the concentration of suspended organic particles in the lower layers of the water column represents an increase in food supply and filter-feeding animals generally benefit. However, many toxic substances are associated with organic particles and an increase in the supply of the latter may result in an increased exposure to the former. However, an increase in the concentration of inorganic particles could be detrimental because the organisms have to expend energy dealing with more particles of low nutritional value. Large increases in organic or inorganic particles tend to have detrimental effects by overloading feeding processes, damaging feeding structures or smothering organisms. Development, growth and survival of suspension feeders were negatively influenced by high levels of suspended solids (Grecay, 1989). The result is generally a shift in community structure away from filter-feeding animals in favour of deposit feeding animals.

Besides natural high turbidity areas (e.g. estuaries, fronts), turbidity can also be caused by human interventions, like dredging. A short but very high impact from a dredging activity may cause mortality, but not always. Sometimes dredging that causes very high levels of turbidity for a short period of time can be less invasive and less of a problem for marine life than dredging more slowly and creating lower level turbidity that persists for a longer period of time.

4.2.5 Oxygen

When food supply from the water column to the sea floor is high, this results in increased oxygen stress (high oxygen consumption), which can reduce the benthic faunal diversity or even result in depletion due to the death of benthic fauna (Aertebjerg et al., 2003). Oxygen depletion will lead to a further reduction in species diversity, and mass mortality of most organisms, especially due to production of H_2S in sediments. In general, fishes are more sensitive to hypoxia than crustaceans and echinoderms, which in turn are more sensitive than annelids, whilst molluscs are the least sensitive. Growth is affected at oxygen concentrations between 6.0 and 4.5 mg O_2/l; other aspects of metabolism are affected at concentrations between 4 and 2 mg O_2/l and mortality occurs where concentrations are below 2.0 to 0.5 mg O_2/l (Gray et al., 2002). Recovery to a community structure that is normal to a particular habitat depends on several environmental factors, e.g. severity of the hypoxia (Llansó 1992), salinity, temperature, current regimes, latitude, etc. Recovery is generally more rapid in shallow waters than in deeper waters (Diaz & Rosenberg 1995).

Patterns observed at the Belgian Continental Shelf indicate a dependence of the benthos on pelagicaly produced organic carbon (Steyaert, 2003, Vanaverbeke et al., 2004). A time lag between deposition and mineralisation of organic matter in coastal, fine grained sediments results in oxygen stress from spring to late summer (Vanaverbeke et al., 2008), but negative effects have never been recorded at these stations. However, it should be mentioned that the most stressed sediments on the BCS, situated near the mouth of the Westerschelde, have not yet been intensively studied regarding this aspect. This lack of knowledge will be dealt with in the current EUTROF project.

4.2.6 Heavy metals (Fe, Zn, Cu, Cd) and chemical contaminants

Chronic heavy pollution of the bottom sediments leads to a decrease in the biodiversity of the infauna and to specific metal-tolerant communities (Davydkova et al., 2005). Effects of heavy metals on the bottom fauna were most observed nearby harbours, where higher concentrations of heavy metals in animal tissues were found. Also nearby dumping sites (mostly dredged material from the harbours), the concentrations of most heavy metals were higher than in reference areas (Lauwaert et al., 2008).

Due to international measures, the input of most compounds has been drastically reduced, and levels in the environment did accordingly. For metals, levels observed are usually within safe limits. The measures taken to reduce both atmospheric and waterborne inputs did have their effect. Mercury concentrations in sediments range from 0.005-0.25 mg/kg d.w., the higher values are found near dredged spoil disposal sites. Values for Hg in fish and shellfish usually range from 0.01-0.1 mg/kg w.w. Values are significantly lower compared to 20 years ago, but, the decrease has almost stopped in the latest years. The same is true for other metals. Speciation of metals can reveal problems, since several organometallic compounds are much more dangerous than the metal itself.

An example is tributyltin (TBT), used on ship hulls as an antifouling agent, reducing the friction of the vessel in the water column and so saving enormously on fuel costs. The residue and breakdown products are abundant in harbors and marinas, and near shipping lanes. Since the BCS is rich in all of them, the problem is huge, most concentrations being way outside safe limits. Moreover, TBT tends to accumulate in crustaceans like brown shrimp (*Crangon crangon*), a commercially important organism and can cause imposex problems in gastropods. More investigation on this topic is required to determine whether TBT has an effect on the local gastropod communities. The half live time of TBT in the environment is estimated at approximately 11 years; the breakdown firstly yields DiButylTin(DBT), than MonoButylTin (MBT). The sum of these three compouns varies from 0.15 to 22.5 µg/kg d.w. in sediments from the BCS. 14 out of 21 stations exceed the limit of 5 µg/kg d.w., considered as maximum for environmental risk.

PCB (Polychlorinated Biphenyls) levels dropped significantly during the last years; the ban of these products was successful. The sum of PCBs was always below 20 µg/kg d.w. in the sediment, whilst values from 30-70 µg/kg d.w. were common in the nineties. In biota, only exceptionally values above 75 µg/kg w.w. are encountered, rendering them virtually all suitable for consumption. Care has to be taken with the consumption of fish liver, fish filet poses no problem.

Chlorinated pesticides are usually hard to detect. In biota, transnonachlor and hexachlorobenzene (HCB) show the highest concentrations. In sediments, DDT and its breakdown products are most abundant, but levels are generally quite low in both matrices.

PAHs can form a local and temporal problem. Metabolisation by fish is fast; in shellfish, however, they can mount up to high concentrations. Close to shipping lanes, their TEQ value or "benzo-a-pyrene (BaP) equivalent" (all values multiplied by toxicity relative to BaP) in shellfish ranges typically from 10-30 µg/kg w.w., more distant from non-detectable to 5 µg/kg w.w.

Recent studies identified antibiotic residues to be detectable in fish close to the shore. This needs further follow-up, and is a matter of concern.

Residues of ethinyl-oestradiol are measurable in seawater from the BCS. These substances can cause endocrine disruption. Ovotestes (ovary cells in the testes) in fish from the BCS are not uncommon. Wastewater treatment plants have to make sure that they achieve a proper breakdown of these products. The high number of women using this kind of contraceptiva forms the cause. The problem is even bigger in drinking water production facilities, who have (treated) surface water as intake. Residues pose a threat to young children.

Perfluorinated chemicals are ubiquitous in the environment. Values within the Scheldt estuary and near the mouth are very high, due to the presence of a production facility (3M) near Antwerpen. Due to an accidental spill, a big area has been heavily contaminated. The bioaccumulating compounds PFOS (Perfluorooctyl sulfonic acid) and PFOA (Perfluorooctanoic acid) are replaced by short-chained homologues like PFBS (Perfluorobutyl sulfonic acid). These have way less bioaccumulating potential, but are detectable all over the Northern hemisphere and are very long-lived compounds with unknown toxic characteristics.

In Belgium, ILVO-fisheries is responsible for the monitoring of several animal species (crustaceans, fish and shellfish, sea anemones and sea stars) and of sediment samples (fraction <63µm) on the BCS. Data are collected for several purposes. Samples for metal (Hg, Cd, Pb, Cr, Cu, Zn & As) analysis are sent to CODA, Tervuren. The main target organic components are PCBs (IUPAC nrs 28, 31, 52, 101, 105, 118, 138, 153, 156 & 180), chlorinated pesticides (alpha-HCH, lindane, aldrin, dieldrin, endrin, transnonachlor, HCB, p,p'-DDT, p,p'-DDE and p,p'-TDE), and PAHs (acenaphtylene, acenaphtene, anthracene, phenantrene, fluorene, fluoranthene, chrysene, pyrene, benzo(a)-pyrene, benzo(b)-fluoranthene, benzo(k)-fluoranthene, benz(a)- anthracene, dibenz(a,h)- anthracene, benzo(g,h,i)-perylene & indeno-1,2,3-(c,d)-pyrene). Organotin and brominated flame retardant analysis is performed at MUMM (Oostende).

4.2.7 Fisheries

Three studies, summarized below, showed that fishing (trawling) has a negative effect on the bottom fauna.

Collie et al (2001) shows that intertidal dredging and scallop dredging have the greatest initial effects on benthic biota, while trawling has less effect. Fauna in stable gravel, mud and biogenic habitats are more adversely affected than those in less consolidated coarse sediments. The recovery rate appears to be most rapid in these less physically stable habitats, which are generally inhabited by more opportunistic species. However, areas that are fished more than three times per year (parts of the North Sea) are likely to be maintained in a permanently altered state. It can be concluded that intuition about how fishing ought to affect benthic communities is generally supported, but that there are substantial gaps in the available data, which urgently need to be filled. In particular, data on impacts and recovery of epifaunal structure-forming benthic communities are badly needed.

Bergman & Hup (1992) shows that the presence of certain species of benthic infauna in catches from a beamtrawl indicated that tickler chains and the ground chain can scrape off successive layers of sediment and reach at least 6 cm into the sediment. Direct effects of beamtrawling on benthic species in the North Sea were determined by comparing faunal abundance before and after commercial beamtrawling on a hard-sandy sediment. In autumn 1989, three-fold trawling of an experimental area resulted in a decrease in density (10–65%) of a number of species of echinoderms, polychaetes and molluscs (Bergman & Hup, 1992).

Hiddink et al. (2006) show that bottom trawling causes widespread disturbance of sediments in shelf seas and can have a negative impact on benthic fauna. A large-scale assessment of the effects of bottom trawl fishing on benthic fauna in different habitats was conducted, using a theoretical, size-based model that included habitat features. Species richness was estimated based on a generalized body mass versus species richness relationship. The model was validated by sampling 33 stations subject to a range of trawling intensities in four shallow, soft sediment areas in the North Sea. Both the model and the field data demonstrated that trawling reduced biomass, production, and species richness. The impacts of trawling were greatest in areas with low levels of natural disturbance, while the impact of trawling was small in areas with high rates of natural disturbance. For the North Sea, the model showed that the bottom trawl fleet reduced benthic biomass and production by 56% and 21%, respectively, compared with an unfished situation. Because of the many simplifications and assumptions required to synthesize these data, additional work is required to refine the model and evaluate applicability in other geographic areas. The model enables managers to understand the consequences of altering the distribution of fishing activities on benthic production and hence on food web processes.

In the Belgian part of the North Sea, fishery has an overall impact on the benthic community, causing physical disturbance and the inhibition of the development of stable structures or the occurence of longer living species in soft-bottom substrates

In the BPNS several impact studies have been performed to quantify the impact on the biogenic stable habitat formed by *Lanice conchilega*. This species qualifies as reef builder (Rabaut et al., 2009). The, resilience of the particular *L. conchilega* system to beam trawl fisheries has been investigated in a set of laboratory experiments. Results show that *L. conchilega* is relatively resistant to intermediate fishing pressure. To test for the impact on ecosystem level, experimental trawling was done *in situ*. In this case, it was shown that species which are strongly associated with the *L. conchilega* aggregations are greatly impacted after fishery disturbance (Rabaut *et al*. 2008)).

4.2.8 Climate change

Over the last two decades, changes in total abundance and biomass of macrobenthos were observed in Danish open sea areas. Correlation analyses performed between the biological variables and two environmental variables related to climate, the North Atlantic Oscillation index (NAO-index) and runoff of freshwater from Denmark, showed significant positive correlation with a 1 or 2 year time lag, indicating influence of climate on benthic variations (Henriksen et al. 2001). This shows that the benthic variation observed in a region is also triggered by the climate change process.

Therefore, the predicted effects of measures taken in an area to improve the ecological status have to be viewed in relation to the climate change. The climate change will negatively affect the measures taken to reduce the eutrophication problem due to the increased temperature (favouring phytoplankton blooms) and the higher run-off (more nutrients and other substance will enter the marine environment).

4.2.9 Overview

The benthic respons to different environmental variables is not always straightforward and depends strongly on the region, type of habitat, intensity of the pressure, hydrodynamic conditions, the resilience of the benthic animals, etc… . It is not easy to summarize the benthic responses to changing environmental variables, but in table 4, the main patterns were outlined.

Table 4. Overview of the respons of benthos to changing environmental parameters.

Environmental parameter	Pattern	Benthic respons
Nutrients	Increases lead to eutrophication problems (higher primary production, nuisance algae)	Indirect respons leading to a lower species diversity and biomass, and a higher density. Strong eutrophication leads to a decrease in all benthic parameters. See Pearson & Rosenberg relation (Figure 4).
Plankton variables	Higher primary production, leading to eutrophication	Same respons as to increased nutrient loads. Species substitutions from suspension feeders to deposit feeders.
Organic carbon content	High values of organic carbon load	Decrease in diversity, density and biomass.
Oxygen	Oxygen deficiency	Reduction in species diversity

	Anoxia	No benthic life
Turbidity	High turbidity	Switch in benthic community from suspension to deposit feeders
Heavy metals	Chronic pollution of heavy metals (e.g. harbors)	Decrease in species diversity
Chemical substances	TBT	Causing imposex in gastropods
Fishery	Physical disturbance of the seafloor	Decrease in density and biomass of a lot of benthic species (rate of decrease is species dependent) Transition to short-living, opportinistic species
Climate change	Increased river run-off, leading to an intensification of the eutrophication. Sea temperature rise	Positive benthic response will be delayed. Species shift (southern species) and time-shift problems in reproduction.

4.3 Modelling

Nowadays, the modelling work with regard to benthic invertebrates focuses on the following two main types of predictive modelling: (1) one based on multiple discriminant functions to predict the macro- invertebrate fauna for new sites (Degraer et al., 2002) and (2) one based on multiple linear regressions to find the best equation between a biological and environmental parameter (Ysebaert & Herman, 2002). This type is mainly used to investigate and quantify the dependence of certain species to certain environmental parameters. The first model approach is used in local areas to determine the potential of a certain area for a certain type of benthic community or benthic species (Verfaillie, 2008) and is mainly based on sedimentological characteristics. This habitat suitability modelling is well-developed for the Belgian coastal waters, which already resulted in the creation of full coverage maps of the potential occurrence of the different benthic communities on the Belgian Continental shelf. These predictions were fully based on sedimentological variables, which were the most important variables to determine the occurrence of certain benthic communities or benthic species. These types of modelling (**static models**) were used to explain the occurrence of species or benthic characteristics under certain environmental conditions, but they do not predict or reflect the patterns in benthic characteristics in relation to changing environmental conditions (e.g. modelling and quantifing the Pearson & Rosenberg model). Ideally in this context, ecosystem models have to be developed that quantify benthic characteristics within the ecosystem (chemical, physical and biological). This type of ecosystem modelling (**dynamic models**) is not static in time but is still restricted in their spatial resolution (box models). The model formulations are usually more complex and non-linear. They are heuristic, attempting to represent the consequences of processes throughout a system. This modelling approach with benthos is in a preliminary phase, as outlined below.

A lot of models exist to quantify the relations between the ecosystem components (chemical, physical and biological). Due to complexity, most models focus on specific relations within the ecosystem model. The best developed modelling approaches in our region are the three-dimensional ones which describe and predict how the marine ecosystem of the greater North Sea area functions and how concentrations and fluxes of biologically important elements vary in space and time, throughout the area and over years, in response to physical forcing (Moll & Radach, 2003; Radach & Moll, 2006; OSPAR report 373/2008). These types of models are important to investigate what the effect of the nutrient reduction scenario's, the main focus in the measure introduced for the WFD, are to reduce euthrophication in the North Sea and on the ecosystem function. The nutrient reduction would primarily have a more direct effect on phytoplankton (chlorophyll A, *Phaeocystis* blooms, primary production), than on benthos. Changes in phytoplankton will have an indirect influence on the benthos, due to the bentho-pelagic coupling (deposition of organic matter and nutrient release by benthos). Next to a possible decrease in food input to the seafloor, the oxygen conditions can improve, which positively influences the state of the benthos. Therefore, most models deal with the effect of eutrophication on the phytoplankton components (chlorophyll, *Phaeocystis* blooms), without a direct link with the benthos component. Most 3D-models used in the greater North Sea introduced a benthic system for nutrient remineralisation by indirect mechanisms or used up to four explicit state variables for nutrients in the benthic bottom layer, except the ERSEM models, which has real zoobenthos variables (ERSEM and POL3d-ERSEM) (Moll & Radach, 2003). Current numerical ecosystem models are limited to a small number of benthic variables on a level of functional/taxonomic groups. To simulate the dynamics within the benthos itself, a more detailed concept of trophic and non trophic processess acting between the benthic organisms is needed. This section summarizes the important models of this type and the potentials to link their system to a benthic component.

For the Belgian waters, the effects of changes in nutrients on phytoplankton are modelled by the MIRO&CO-model in combination with RIVERSTRAHLER (Lancelot et al., 2005, Lancelot et al., 2007), which made it possible to make some predictions on the phytoplankton characteristics at changing nutrient concentrations. The MIRO biogeochemical model models the link between anthropogenic nutrient loads and the magnitude and extent of diatom and *Phaeocystis* colony blooms in the Southern bight of the North Sea. Coherens-3D is a hydrodynamic model for the southern bight of the North Sea and Channel. The RIVERSTRAHLER model is a generic model of the biogeochemical functioning of an entire river system, calculating the water flows through the drainage network, with a module describing the kinetics of the biological, and physical-chemical in-stream processes (Billen et al., 1994). This model is used to predict realistic nutrient river input predictions towards the marine waters. The MIRO model includes a benthic compartment to describe the remineralisation of nutrients by benthic fauna. The calculated parameters are benthic organic matter degradation and nutrient (N, P, Si) recycling by the algorithms developed by Lancelot & Billen (1985) and Billen et al. (1989). These algorithms, by solving steady-state diagenetic equations expressing the mass balance of organic C, oxygen and inorganic forms of N and P in the sedimentary column, calculate the fluxes of NO_3, NH_4 and PO_4 across the sediment-water interface resulting from a given sedimentation flux of POM. The biogeochemical processes in the benthic compartment are taken into account, but no biological variables of benthic parameters. This is the same for all other models of this type, except the ERSEM models, which have real zoobenthos variables (ERSEM and POL3d-ERSEM). The benthic submodel of the ERSEM, the generic European Regional Seas Ecosystem was represented by a detritus pool and seven functional groups (aerobic and anaerobic bacteria, meiofauna deposit and filter feeders, epibenthic and infaunal preditors). The benthic submodel itself is one-dimensional, simulating vertical fluxes of organic carbon, oxygen and the nutrients N, P, and Si in a 3 layered bottom (oxygenated, oxidised and reduced layer). This box is linked to the pelagic system mainly by the sedimentation and filtering of organic matter, the export of dead organic material by all trophic levels and nutrient release from the sediment. On a large scale (North Sea), the modelled annual mean macrofaunal biomass correlated well with the data from the North Sea Benthic survey (Künitzer et al., 1992). The ERSEM model made a good prediction of the north-south trend in biomass of the North Sea, but did not reproduce the small-scale features in the vicinity of major estuaries. The disadvantage of this ERSEM model is that the spatial resolution is too coarse in its present box-model version and no temporal simulations were available. There were also other complex dynamic models of estuarine and marine ecosystems with a coupled box structure like the Cumberland Basin Model (Gordon et al., 1986, 1987), the Bristol Channel/Severn estuary model (GEMBASE; Radford & Joint, 1980) and the Ems-Dollart model (BOEDE; Baretta & Ruardij, 1988) which include benthic submodels. But these benthic modelling attempts are suffering from very low numbers of benthic variables and the too generalised formulation of processess, mainly due to the lack of understanding regional processes and the the lack of data for a proper parameterisation. However, these examples show that it is possible to include a biological benthic compartment to make predictions for benthic parameters based on changing processes in the pelagic system and that research should further focus on it.

The main problem in the described models is that it is difficult to quantify most variables/fluxes to benthic parameters (density, biomass, diversity). Of main importance is the downward flux of organic carbon, which can be consumed by the benthic bottom fauna or which can be filtered by suspension feeders. So, a model link can be made between the food from the pelagic environment and the benthic production (biomass). The fraction of primary production reaching the bottom depends on the depth of the system. This is also indirectly quantified by the link between system primary production and system benthic biomass (Herman et al., 1999), where it is assumed that benthos consumes approximately 1/10 of the primary production in a system. A pan-European study of benthos, shows that there is a negative relation between area species richness and the fraction of primary production reaching the bottom (Escaravage et al., submitted), which corresponds with the decreasing part of the unimodel diversity-productivity relation. Furthermore, it is very important to quantify bioturbation processes on food availability and predator-prey relations to describe the benthic sub-model. Another important parameter is the oxygen concentration in the sediment, which is strongly influenced by the amount of decomposing material. One of the indirect effects of eutrophication is oxygen deficiency in the water and sediment. The benthic density and diversity strongly decline when the sediment tends towards anoxic conditions. In essence, this aspect can be brought back to the quantifications and modelling of the Pearson & Rosenberg (1978) relation (e.g. reaction of benthos to organic content enrichment) so that the effects of changing eutrophication can be linked to benthic characteristics (density, biomass, diversity). Therefore, it is important in this context to formulate some further steps and recommendations regarding dynamic modelling research.

The main deficits of the described models are:

- A lack of reliable benthic data for parameterisation of benthic processes, calibration and validation of numerical dynamic models and also a lack of homogeneous data sets of benthic variables on decadal scale to be linked with environmental data and analysed with statistical (uni- and multivariate regression) models.
- The fact that physical processes in the benthic boundary layer like (bio)resuspension, (bio)deposition are identified as significant omissions (e.g. ERSEM model). However, also biological processes linking the pelagic and benthic system like recruitment, relates of eggs/cysts, and the migration of species are missing and would demand specific submodels to develop exchange processes in the benthic boundary layer.
- The lack of approaches of numerical modelling of non-trophic interactions between benthic organisms like competition, interference, and communication
- The lack of a population dynamics/ succession model for North Sea benthos

Some recommendations regarding this topic:

- Sampling designs and experiments for the investigation of benthic processes ought to be planned in cooperation with the modelers to discuss parameters needed for better spatial and temporal resolution of benthic models. The overall monitoring programmes also have to collect next to the necessary benthic information, the related environmental parameters.

- The number of biological parameters in benthic models should be increased, and, if feasible, the models should incorporate more submodels (higher complexity).
- The definition of key species and key processes (e.g. bioturbation; (bio)resuspension/ (bio)deposition; recruitment; migration) is needed for a realistic parameterization of benthic models.
- There is a need for the development of new approaches regarding the numerical modeling of trophic and non-trophic interactions between benthic organisms.
- Habitat specific characteristics should be included in the benthic models, e.g. sedimentology which is the main determining variable for benthos. This addition to the models would take into account differences in the quantification of the bottom processes depending on the type of benthic community (related to a certain sediment type). The benthic processes (oxygen consumption, organic carbon content break down), for example, will differ in a diverse fine muddy sand community, compared to a rather poor coarse sandy community.
- A stronger link between statistical and numerical modelling is needed. Statistical analysis of appropriate data can detect ecological relationships that yield hypotheses which can be tested in dynamical modeling.
- Models including disturbance (natural and anthropogenic) of benthic communities should be elaborated on. The reactions of benthos to certain disturbances have already been defined by Pearson & Rosenberg and can further be quantified.

4.4 Long-term trends of coastal benthos

Benthos in coastal regions is subject to strong natural variability (seasonal and year-to-year) (Van Hoey et al., 2007). Long-term analysis of benthos characteristics can help to understand how this trend can influence the ecological status of the benthos. Trends in benthic parameters can be evaluated based on long-term data over 30 years at three coastal stations (120, 140, 700), monitored by ILVO. Based on this information, insight can be obtained on the variability of the benthos at the Belgian coast and how it has evolved over the last decades.

Station 120

Station 120 is situated at the west coast in front of Nieuwpoort harbour and is characterised by muddy fine sand (average median grain size ± 200µm, mud content between 2-10%). The sedimentological composition has not really changed over the last 30 years. This station is limitedly influenced by riverine and harbour outputs and the main anthropogenic pressures are fishery (beamtrawl) and eutrophication. The density and number of species were rather stable from 1982 onwards, with a small decline in 1995-1996, due to the dominance of *Spisula subtruncata* (Figure 5). Lower values at the end of the seventies for number of species and density were observed. The biomass was highest in the middle '90's, due to a very succesfull recruitment of *S. subtruncata*. The density remained rather stable over the investigated period. It can be concluded that there were no obvious changes at station 120 over the last 30 years in overall characteristics of the benthos.

These patterns were confirmed in the multivariate analyses (MDS plot, Figure 6), where three main cluster groups were identified. Cluster one, contains mainly samples from before 1983, characterised by a lower density (1438 ind/m²) and species richness (17 species/0,1m²) compared to the other clusters (Table 5). Cluster two, containes the samples of 1996, characterised by *S. subtruncata* and low density and species richness. Cluster three, containes the samples of 1984-2000, characterised by the highest average density (3047 ind/m²) and species richness (29 species/0,1m²) and the typical species of the *Abra alba* community (Van Hoey et al., 2005). Cluster four contains the samples of 2000 onwards and the main characteristic species were Cirratulidae spp. and *Abra alba*. The species diversity (25 species/0,1m²) is comparable with cluster three, whereas the average density (1935 ind/m²) is lower. There was a slight change in species composition at station 120 in correspondance with the time series.

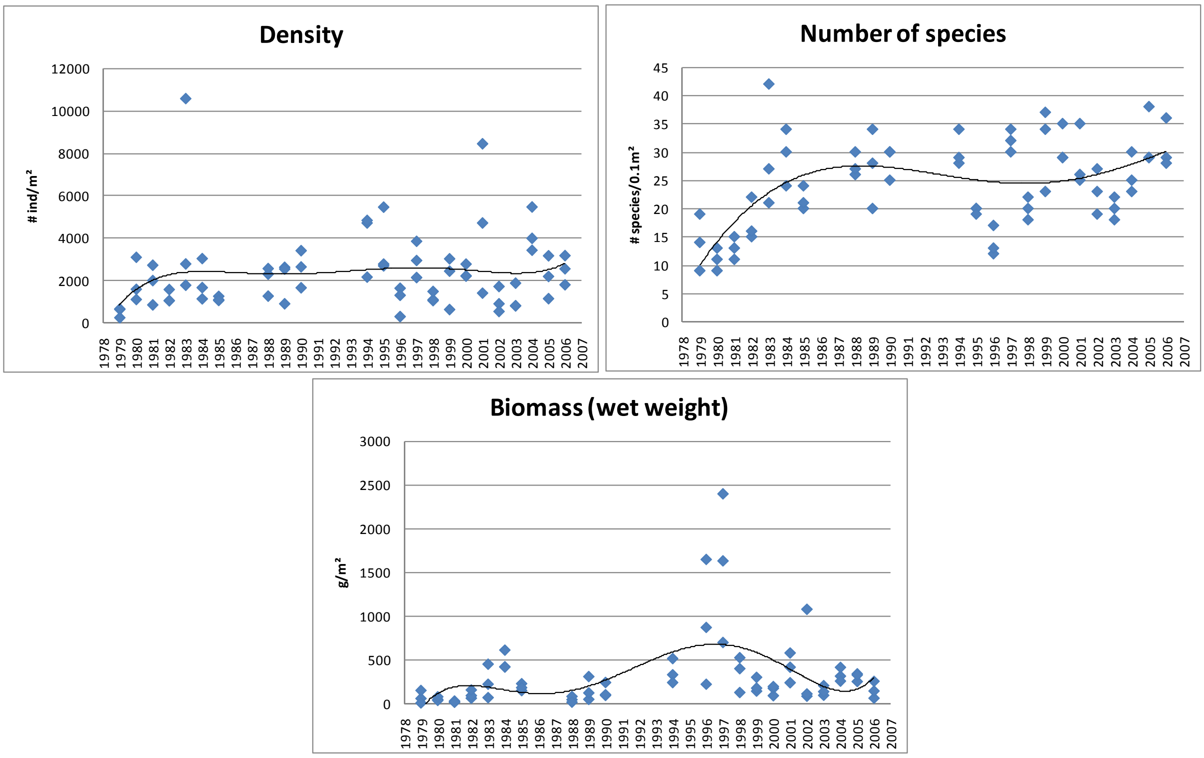

Figure 5. Pattern for density, number of species and biomass (wet weight) over 30 years at station 120. The trend line is a polynomial (5the order).

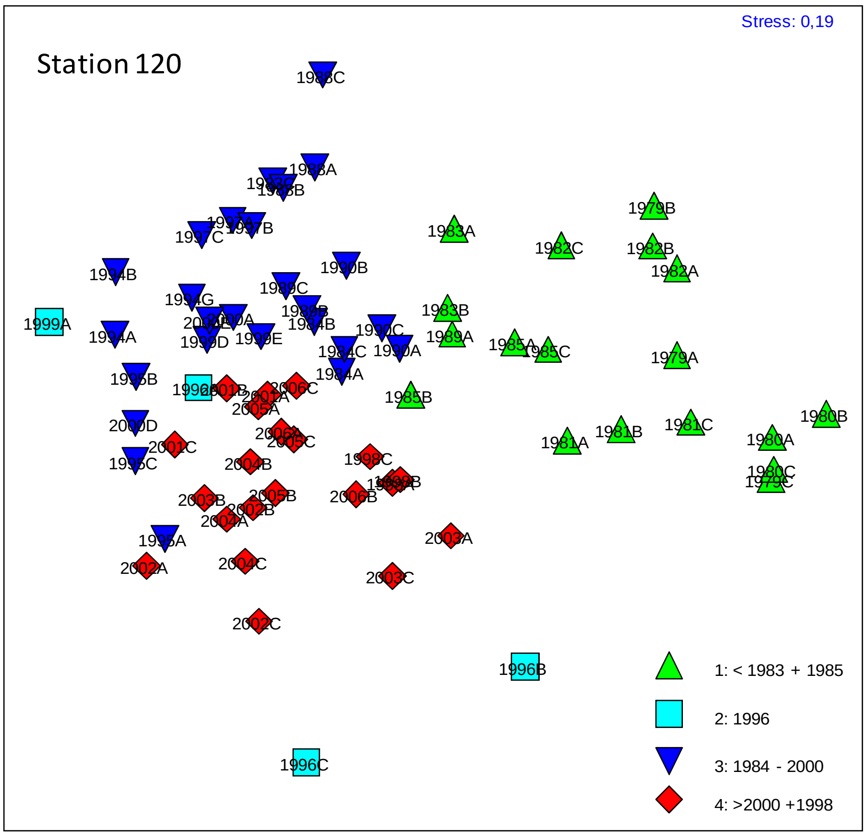

Figure 6. MDS plot of station 120 (replicate's separated), with indication of the 4 clustergroups.

Table 5. Species top 5 of the SIMPER analyses of the species contribution to the similarity within each cluster group (with average abundance and contribution %), the average density of the samples, total number of species and the average number of species per sample.

Station 120											
Group 1: < 1983 + 1985			Group 2: 1996			Group 3: 1984-2000			Group 4: > 2000 + 1998		
Species	Av. Abund	Contrib%	Species	Av. Abund	Contrib%	Species	Av. Abund	Contrib%	Species	Av. Abund	Contrib%
Mysella bidentata	313	16,55	*Spisula subtruncata*	267	26,98	*Abra alba*	327	15,56	Cirratulidae spp.	251	20,05
Nephtys spp,	77	16,15	*Scoloplos armiger*	55	19,08	*Pariambus typicus*	402	11,63	*Abra alba*	181	16,84
Nephtys hombergii	60	10,9	*Cirratulidae spp.*	165	16,88	*Nephtys spp,*	149	7,78	*Spiophanes bombyx*	121	8,44
Pectinaria koreni	326	10,74	*Mysella bidentata*	130	11,94	*Spiophanes bombyx*	133	6,37	*Notomastus latericeus*	87	6,93
Fabulina fabula	112	9,65	*Heteromastus filiformis*	30	5,12	*Eumida sanguinea*	193	5,97	*Scoloplos armiger*	100	6,81
avg dens	1438		avg dens	990		avg dens	3047		avg dens	1935	
# species	53		# species	35		# species	80		# species	67	
Avg # species	17		Avg # species	16		Avg # species	29		Avg # species	25	

Station 700											
Group 1: outliers			Group 2: 1979-1999			Group 3: > 2000 + 1985, 1993			Group 4: outliers (poor stations)		
Species	Av. Abund	Contrib%	Species	Av. Abund	Contrib%	Species	Av. Abund	Contrib%	Species	Av. Abund	Contrib%
Petricola pholadiformis	13	100	*Petricola pholadiformis*	990	34,32	*Cirratulidae*	255	73,16	*Barnea candida*	60	73,58
			Polydora spp.	4580	30,17	*Nephtys spp.*	33	10,5	*Mytilus edulis*	11	12,83
			Corophium spp.	825	15,28	*Pectinaria koreni*	40	2,44	*Polydora spp.*	12	7,76
			Abra alba	792	5,72	*Nephtys hombergii*	7	1,88			
			Nereis succinea	111	3,04	*Diastylis rathkei*	12	1,63			
avg dens	46		avg dens	1043		avg dens	520		avg dens	96	
# species	7		# species	48		# species	33		# species	16	
Avg # species	3		Avg # species	13		Avg # species	7		Avg # species	4	

Station 140														
Group 1: outliers			Group 2: 1983+1994+1998+2002-2003			Group 3: 1985 + 1993			Group 4: 1979-1981 + 1986-1990 + 1996			Group 5: 1997 + 2001 + 2006 (poor stations)		
Species	Av. Abund	Contrib%	Species	Av. Abund	Contrib%	Species	Av. Abund	Contrib%	Species	Av. Abund	Contrib%	Species	Av. Abund	Contrib%
Nephtys spp.	12	38,25	Cirratulidae spp.	152	26,7	Cirratulidae spp.	250	43,39	*Nephtys spp.*	117	49,39	Cirratulidae spp.	142	89,12
Diastylis spp.	5	24,77	*Spio spp.*	200	22,58	*Pectinaria koreni*	68	29,84	*Diastylis spp.*	33	25,12	*Nephtys spp.*	7	9,06
Abra alba	5	8,98	*Nephtys spp.*	76	18,25	*Corophium spp.*	81	8,14	Cirratulidae spp.	173	20,62			
Spisula subtruncata	10	8,51	*Abra alba*	58	9,97	*Diastylis spp.*	21	6,88						
Macoma balthica	3	4,19	*Spisula subtruncata*	191	6,41	*Macoma balthica*	33	4,77						
avg dens	71		avg dens	830		avg dens	533		avg dens	375		avg dens	156	
# species	23		# species	33		# species	18		# species	27		# species	5	
Avg # species	4		Avg # species	10		Avg # species	7		Avg # species	5		Avg # species	2	

Station 140

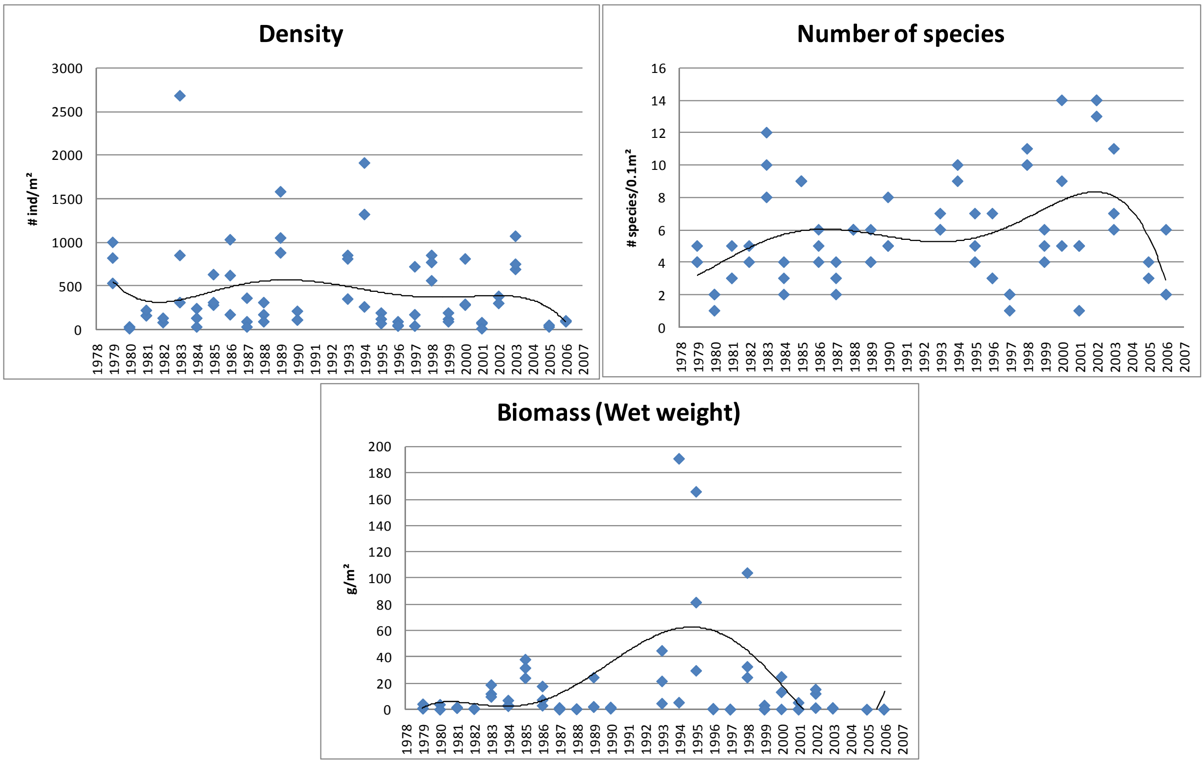

Figure 7. Pattern for density, number of species and biomass (wet weight) over 30 years at station 140. The trend line is a polynomial (5^{the} order).

Station 140 is situated westwards of the harbour of Zeebrugge and is characterised by muddy sediment. The density at this station was mostly lower than 1000 ind/m², but was very low in the last 2 years (2005-2006) (Figure 7). The number of species gradually increased during the observed period, with a decline in recent years. The biomass at this station was rather low, except in the period 1994-1998, due to occurrence of *Spisula subtruncata*. This station is characterised by a rather poor benthic community.

The multivariate analysis (MDS plot, figure 8) reveals no clear pattern in the time series, but rather groups the sample years according their characteristics (species, density). Cluster two contains the samples of the years where a rather diverse (10 species/0,1m²) and dense (830 ind/m²) benthic community was found at station 140, compared to the other clusters. The two outlier cluster groups (one and five), were characterised by a low species diversity and density. Cluster four contains mainly samples of the '80's and were characterised by *Nephtys spp, Diastylis spp* and *Cirratulidae spp.,* but a low species diversity. A succession during the time serie at station 140 is not so clear compared to the other stations, based on the multivariate analysis.

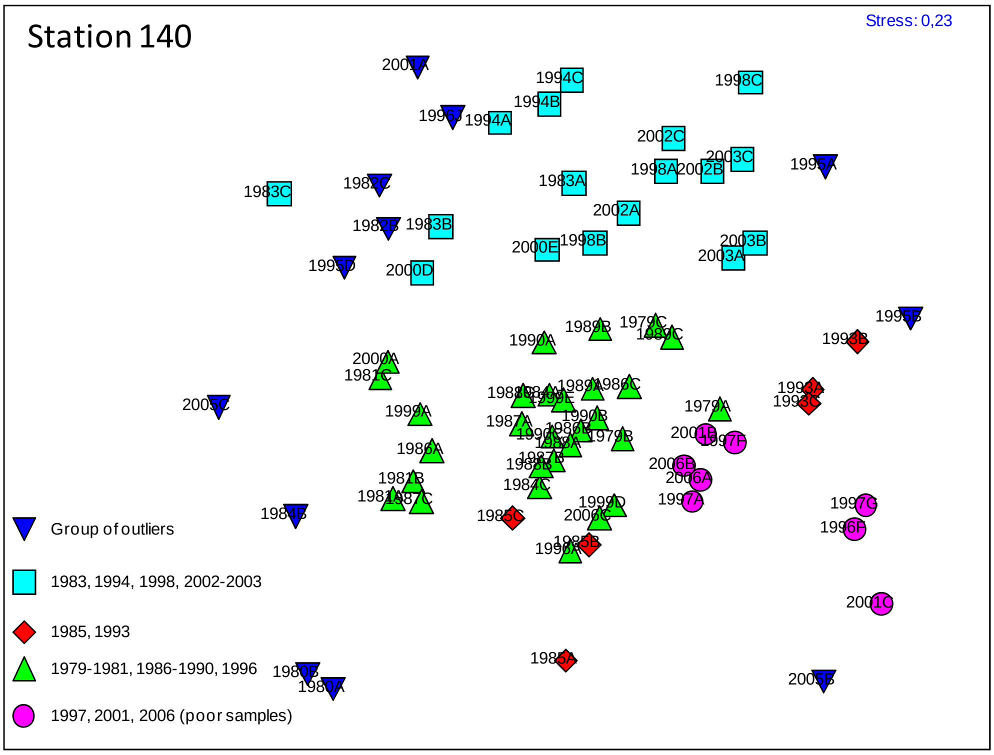

Figure 8. MDS plot of station 140 (replicate's separated), with indication of the 5 clustergroups.

Station 700

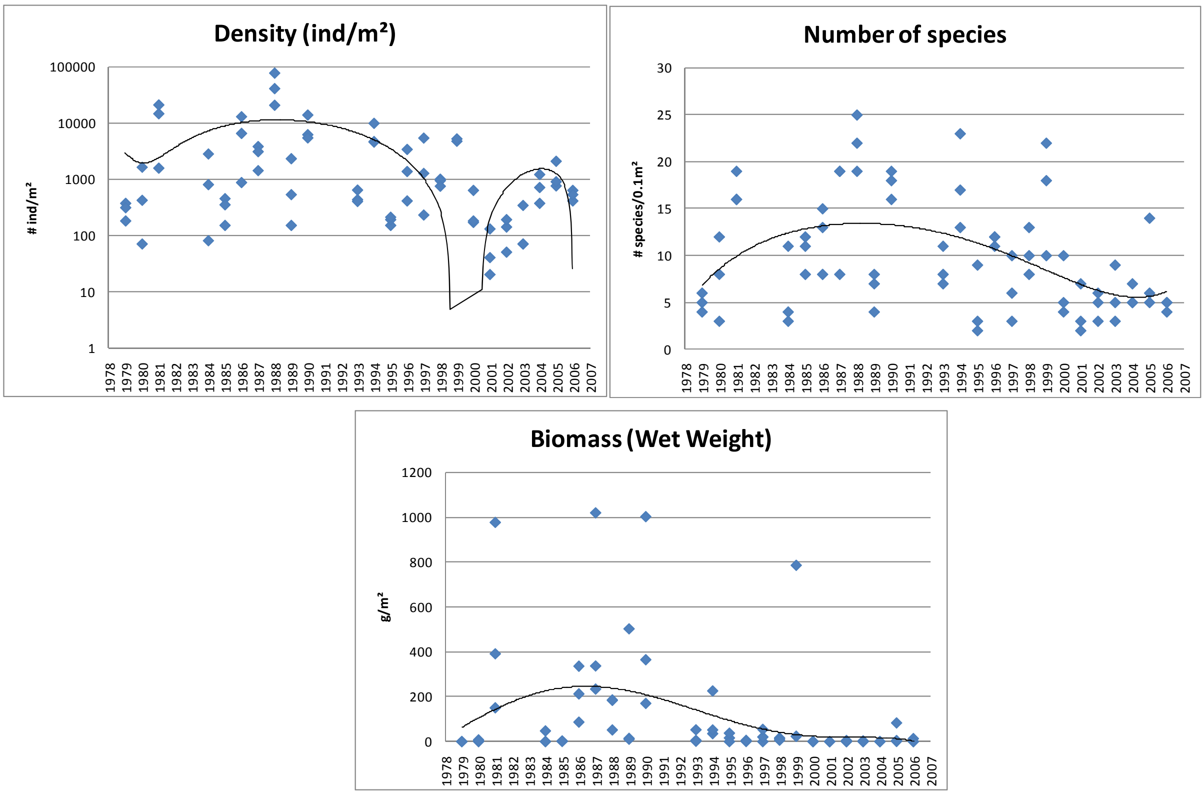

Figure 9. Pattern for density, number of species and biomass (wet weight) over 30 years at station 700. The trend line is a polynomial (5[the] order).

Station 700 is situated nearby the entrance gully of the harbour of Zeebrugge, and is characterized by very muddy sediments. The benthos at this station is strongly influenced by the enlargement works of the harbour of Zeebrugge at the end of the seventies. A dumping site for dredged material is located in the vicinity of this station and influences its sedimentology (mud concentration).

The benthic parameters at this station in autumn show a consistent pattern of lower values at the end of the seventies and beginning of the eighties, whereafter maximal values were observed in the eighties, followed by a slow decrease in the nineties (Figure 9). From 2000 on, the values of density, biomass and number of species strongly decreased. From 1986 – 1990, the benthos at station 700 was characterised by dense populations of *Corophium spp, Petricola pholadiformis* and *Polydora spp* and a rather diverse benthic community for this type of sediment. After 2000, the benthos was characterised by low diversity, densities and biomass and the dominant species group *Cirratulidae spp*.

Mainly the disappearance of *Corophium spp* and *Polydora spp* since the '90's was responsible for the decrease in the benthic characteristics at station 700 (Figure 10). Changes in the hydrodynamics and sediment stability could be responsible for this disappearance. These species makes tunnels within the sediment and cause an increase in the oxygen availability in the sediment, of which other species can profit. *Polydora spp* are opportunistic, but *Corophium spp* need more stable conditions. These species show a high variability in their density, but from the '90's onwards, the populations were unable to maintain themselves. The appearance and dominance of the very opportunistic species *Cirratulidae spp* and *Oligochaeta spp* indicates that the conditions had worsened for benthos, probably due to low oxygen availability in the sediment, high organic carbon content, instability of the sediment due to the dredging, and dumping activities in the neighbourhood.

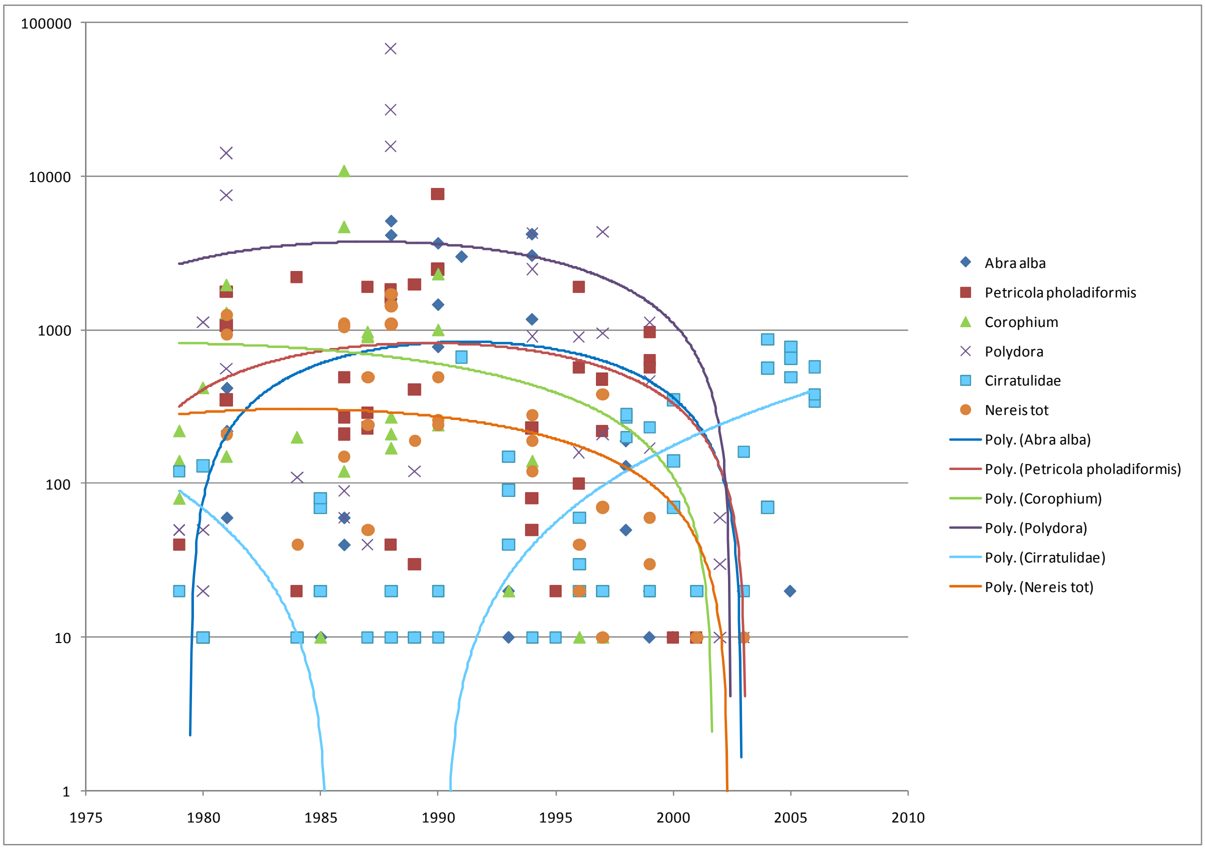

Figure 10. Patterns in density of a few selected species at station 700. The trend line is a polynomial (2the order).

These patterns were confirmed in the multivariate analyses (MDS plot, Figure 11), where two main cluster groups were indentified, one with the samples prior to 2000 (cluster 2) and one with mainly samples of 2000 onwards (cluster 3). Clusters 3, 1 and 4 also contain samples taken prior to 2000, but were mainly characterised by a poor species diversity (<10 species/0,1m²). Cluster 2 is characterised by high densities of *Petricola pholadiformis, Corophium spp* and *Polydora spp* and a higher average number of species (13 species/0,1m²) compared to the other clusters (Table 8). Cluster 3 is mainly characterised by *Cirratulidae spp* and a rather low species diversity compared to the other cluster.

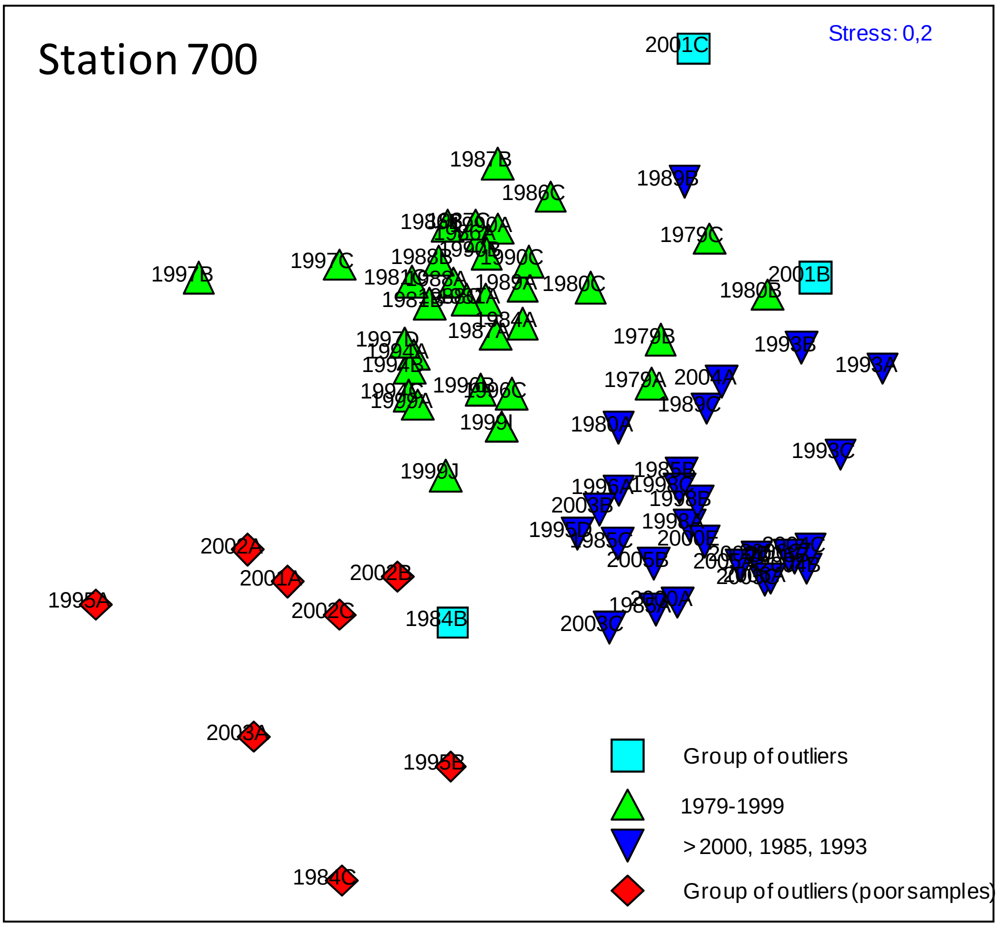

Figure 11. MDS plot of station 700 (replicate's separated), with indication of the 4 clustergroups.

<u>Conclusion</u>

It seems that the benthic characteristics in the Belgian coastal region are rather stable, with some fluctuations due to the dominance of certain species during a certain period. The slight increase in number of species observed at stations 120 and 140 can be the result of an improved taxonomic knowledge in recent years, in combination with a natural increase of the number of species. Whether the stronger species richness increase at the end of the 70's - beginning of the '80's was natural can not be scientifically confirmed, since differences in sampling methodology (ship position, sample processing, taxonomic knowledge) may have resulted in similar trends. The variation in the benthic parameters for the stations 140 and 700 were greater, which were indications of instability in this area. Only station 700, nearby the harbour of Zeebrugge, showed strong changes over the three decades, with a more diverse mud community in the 80's, characterised by structuring species (*Polydora spp., Corophium, Petricola pholadiformis*). This type of muddy community has disappeared and was replaced by a very poor benthic mud community from 2000 onwards. The underlying causes for this steep decrease in density, biomass and number of species are unclear, but it is likely that anthropogenic influences were responsible (eutrophication?, harbour of Zeebrugge?, dredging?). At present, the benthic community is strongly dominated by more opportunistic species, like *Cirratulidae spp* and *Oligochaeta spp*. More investigation is needed in this area to find the causes for it.

These patterns were also visible when the benthic characteristics were averaged per decade (Figure 12). At station 700, the density, number of species and biomass decreases steeply per decade. For stations 120 and 140, the density remained stable or increased slowly, whereas the biomass was highest in the 90's. The number of species increased slowly over the decades.

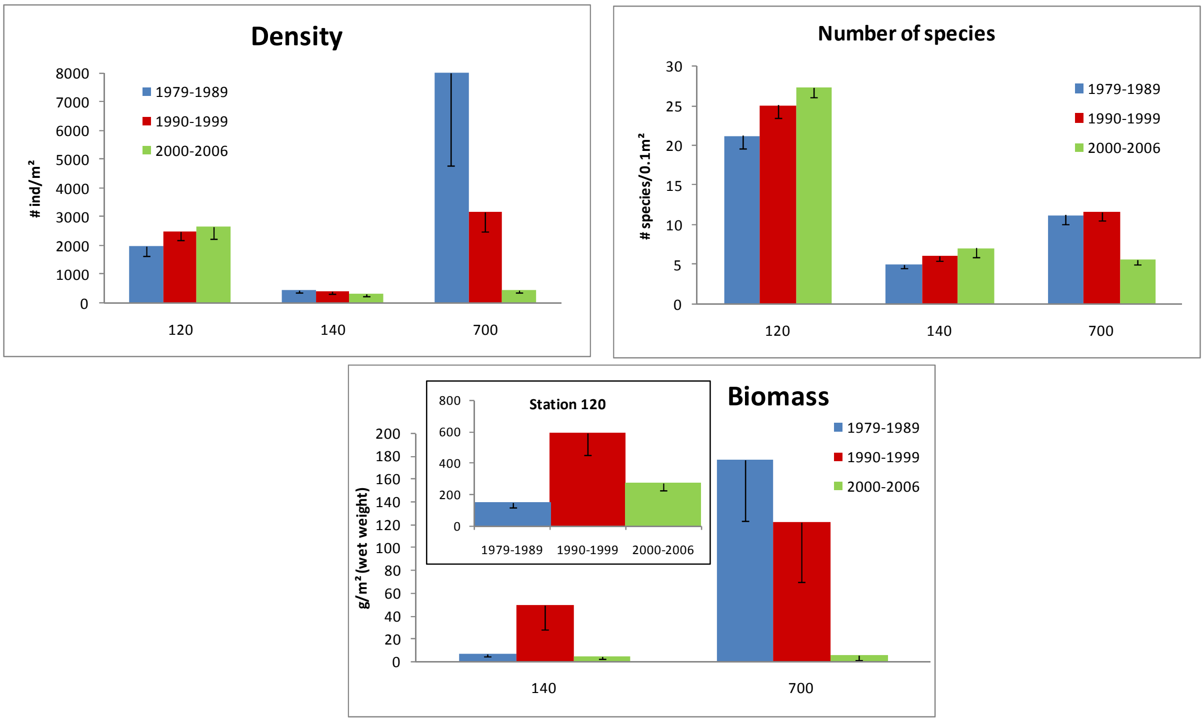

Figure 12. The averages per decade of the benthic characteristics at the three stations.

5 Discussion

In this section, answers/advices will be given to the following questions:

1) Is it possible to reach/maintain the good ecological status of benthos in the Belgian coastal waters by 2015,

2) what will be the ecological status of benthos at the end of each preset period (2021, 2027),

3) are the present measures adequate or are additional measures needed to reach these objectives, and

4) what should the reduced environmental objectives be (if necessary)?

This report will support the Belgian Federal Government in taking decisions concerning the ecological status of the Belgian coast (specifically for macro-invertebrates). Based on the gathered information it should be possible to answer the posed questions. In order to have an expert view on it, these topics were discussed during a benthos expert meeting (20/02/2009); the outcome of this meeting was included in this section. Participants were listed in appendix 1. The overall conclusions can then be used in the WFD management plan for the Belgian coastal waters.

5.1 Is it possible to reach/maintain the good ecological status of benthos in the Belgian coastal waters by 2015?

The current overall ecological status (ES) of benthos in the Belgian Coastal water is good, but in some zones and habitats a moderate status was observed. Especially at the east coast, impoverished benthic conditions were observed compared to the conditions expected based on the reference data (*Macoma balthica* habitat in central and eastern part of the Belgian Coast). It seems that, for the moment, the favourable conditions at the west coast compensate for the more impoverished conditions at the east coast. The ecological status evaluation is based on data of one year (2007), but it is advisable, due to the temporal variability of the benthos, to give a final view on the ES of benthos based on benthos data of at least three years. The monitoring program that will yield the necessary data is in progress.

It seems that, based on the long-term data of benthos at three coastal stations, the benthic characteristics were rather stable, but with changing species dominance over the years. At the east coast, however, conditions were less stable for the benthic community from 2000 onwards, reflected in a strong decrease in diversity and densities of the benthos. The reason and the extent of this impoverishment need to be looked into, but could be related to eutrophication (investigated in EUTROF project), the hydromorphological changes in this area caused by the harbour of Zeebrugge and dredging activities.

➔ Will this situation hold?

Based on the current knowledge of the benthic experts and the observed benthic patterns along the coast, it can be expected that the current situation concerning the ecological status for benthos will hold for at least some years (until 2015). This prediction is based on the current level of the anthropogenic pressures, which are not expected to result further in drastic changes in the benthic characteristics compared to the defined reference conditions. Re-evaluation of this statement is necessary when the current pressures should intensify or extensify (due to the implemented measures). This aspect is also important in the light of the fact that the current benthic reference data is influenced

by the pressures euthrophication and fishery. This because, unimpacted benthos data, related to these pressures does not exist in our region of the North Sea.
Furthermore, it is advisable to determine the current ecological status based on benthic data covering more than one year (monitoring programme is running). An increased power of the analysis, concerning temporal variation, will yield a better estimation of the ecological quality ratios of the benthic parameters and habitats along the Belgian coast.

➔ Will the east coast further impoverish?

The cause for the moderate ecological status of the *Macoma balthica* habitat is not entirely clear and can partly be attributed to the harbour of Zeebrugge. During the expert meeting, the suggestion for further research was raised, since a clear answer to the question could not be formulated (see paragraph about research gaps).

5.2 What will the ecological status of the benthos be in the future (2021, 2027)?

➔ Can we give an expert judgement on the ecological status of benthos in the future?

Since the benthos displays complex links with the environment and because there are many influencing factors (see 4.2), it is difficult to predict the future ecological status of the benthos. For the moment, it is not possible to model the benthic system in such a way that predictions on benthic characteristics under changing environmental conditions can be made (see 4.3). Additionally, no reliable scenarios exist on the environmental changes that will occur in the coastal area due to human water management.
The benthic experts launched the hypothesis that the benthic system along the Belgian coast will not change drastically in the future, but that following factors can influence the ecological status of the benthos:

- **Climate change:** will influence the benthic species composition in the coastal area, but the amplitude of these changes are not yet estimated.
- **Invasive species**: the occurrence and dominance of these species can alter the expected ecological status based on the reference conditions.
- **Changes in the anthropogenic impacts on the benthos**: changes in anthropogenic pressures (e.g. frequency) can evolve in negative as well as positive way.

Following factors can help to maintain or improve the current ecological status (see 5.3 for more details)

- Reduction of the eutrophication problem
- Reduction of the physical impact on the benthos by an improved regulation of the dredging activities and, more importantly, by regulating and reducing the impact of the coastal fishery (beam trawl).

During the expert meeting, it was decided that there were for the moment no signs that the good ecological status of benthos will not be maintained until 2021 and 2027, especially when the anthropogenic pressures in the Belgian Coastal area will be reduced.

➔ What were the additional remarks accompanying this advice?

A re-evaluation of this statement has to be made in every river basin management plan by the benthic experts. Furthermore, additional research is needed concerning certain topics (see below) to support the statement that the good ecological status at the Belgian Coast for benthos will be maintained.

The future ecological status of benthos for the coastal waters in our neighbouring countries can be formulated as:

- In the Netherlands, it is expected that the present moderate status of the coastal waters for phytoplankton and benthos will not change until 2027, but more investigation is needed for confirmation (Ligtvoet et al., 2008).
- In France, it is expected that a good ecological status for benthos in the transitional and coastal waters will be reached.

5.3 Are the present measures adequate or are additional measures needed to reach the WFD objectives?

The current ecological status of the benthos in the coastal waters is rather good, despite a lot of anthropogenic activities which prevent the creation of favourable conditions for the benthic communities along the Belgian coast:

- Intensive fishery activities, causing bottom disturbance
- Eutrophication
- Dredging activities for the harbours and fairway of ships, dumping of dredged material
- Occurrence of invasive species
- Coastal defence works
- Waste discharge from the main harbours (Zeebrugge, Blankenberge, Oostend, Nieuwpoort)
- Occurrence of dangerous substances (heavy metals, PCB, TBT, PAK, …) in the water/sediment and animal tissues
- Shipping
- The ammunition dumping area 'Paardemarkt'

During the expert meeting, the advice was formulated to issue additional measures so that, despite the present good overall ecological status of benthos, additional ameliorations (especially at the east coast) can still be achieved. A further reduction an intensification of the control on these anthropogenic activities will help. Based on the measure programmes in the Scheldt river basin district (section 3), it can be concluded that the current upstream measures mainly tackle the eutrophication and dangerous substances problem. Therefore, the advice to the Federal Government concerning measures will relate to following topics:

- Advices to further reduce the eutrophication in the Scheldt river basin.
- Advices to further reduce the discharge of dangerous substance and waste discharge from the harbours.
- Advices to reduce other anthropogenic impacts (e.g. reducing physical disturbance)?
- Advices related to direct measures, within the authority of the Federal Government
  - The management plans of the Habitat- and Bird Directive areas
  - The MMM-law
  - Global monitoring plan
  - research policy

Eutrophication

Eutrophication is one of the main problems for the coast to reach the WFD objective at the moment, mainly for the quality element phytoplankton, less for benthos. Measures were taken by the regions and countries to act on this problem, but without intelligibility if the eutrophication problem will be solved. The regions and countries focused on waste water treatment and the reduction of discharge from agriculture. The installation of waste water treatment plants is the main focus for the Walloon and Artois-Picardia region, whereas in other regions (the Netherlands) there is a focus on the increase of the performance of existing waste water plants (see section 3). In the Netherlands, it is estimated that the WFD will lead to a reduction of up to 15% for nitrogen and up to 30% for phosphorus in the Scheldt river basin towards 2027 compared to 2005 (Ligtvoet et al., 2008). This will translate in the coastal zone into a reduction of 0 to 10% (coast of Zeeuws-Vlaanderen). In the work of Lacroix et al. (2006) and Lancelot et al., (2007), the models show that for the Belgian Coastal waters, a reduction of more than 75% up to 90% of nitrogen and phosphorus is needed to classify the Belgian coast as a non-problem area for eutrophication under OSPAR. The main problem is the nuisance alga *Phaeocystis,* for which the future management plan has to prioritise on nitrogen reduction. Due to the fact that the current measures will further reduce phosphorus more than nitrogen, the problem of the nuisance alga *Phaeocystis* will only be intensified. The changes in the phytoplankton will also affect the benthos because it is mainly influenced by the eutrophication due to a higher supply of organic carbon and an oxygen decrease in the sediment. Based on the current knowledge, it seems that the Belgian coastal area is characterized by temporal oxygen deficiency in some areas due to the accumulation and break down of detritus in spring-summer. This problem is probably mostly situated along the east coast, but not yet quantified (aim of the EUTROF project). The positive changes in the eutrophication problem will probably be countered by the climate change process, an assumption which needs immediate attention and more investigation.

In short, it seems that the eutrophication problem will not readily be solved and extra effort is advisable.

Consequently, following advices/measures were formulated by the scientists:

- It is advisable that all governments further focus on and investigate the reduction of eutrophication, not only in the waters under their authority, but extra effort should be made to obtain the goals downstream. Therefore, consultation on national and international level has to be continued and even intensified. The upstream regions should make extra efforts to reduce the nitrogen discharge to restore the N/P balance in coastal waters.
- Maintain and intensify the current research about this problem
    - Keep the monitoring running for all parameters (nutrients, phytoplankton, benthos).
    - Further support of science policy projects related to this topic (Timothy, AMORE projecten, Trophos - Westbanks, …)
    - Call for projects that investigate the consequence of the climate change process to this problem.

Further reducing dangerous substances?

The measures related to this topic have the aim to improve the chemical status of the waters and to reduce the occurrence of dangerous substances. For the moment, the concentrations of most dangerous substances are below the accepted level (see 4.2.6) and the main problems are caused by PAH’s, TBT and not yet detectable substances. Of a lot of chemical substances, no information or analytical techniques are available (see 4.2.6) for detection in marine waters. Another problem is that the concentrations of some substances are well above the accepted level in the sediments or animal tissues (e.g. PAH’s in water and sediment), but not in the water column (International Scheldt report 2008). Concentrations of most dangerous substances decreased over the last 20 years, but for the moment their concentrations are stagnating.

It is expected that most substances will not lead to problems in marine waters, except PAH’s and TBT, for which action has to be undertaken.

Following advices were formulated:

- The use of TBT is forbidden, but this prohibition still has to be implemented into Belgian law. Its current presence will continue to cause environmental problems during the next few years. Monitoring is adequate.
- The gastropod *Hinia reticulata* can be a good indicator for TBT problems (e.g. imposex) (Stroben et al., 1992; Barosso et al., 2002) in the Belgian waters. The setup of a monitoring program is advisable.
- The use of the precautionary principle is very important. In this regard, investigation to improve the analytical techniques and the ability to detect limits for a lot of chemical substances in marine waters is needed.
- The problem of the waste discharge from ships and harbours has to be tackled. Solving this problem is essential to reduce the waste problem along the Belgian coast. Next to their own initiatives (e.g. fishing for litter), the Federal Government should discuss this topic with the Flemish Region.

Measures/advices to reduce other anthropogenic impacts?

- Dredging activites

  Dredging activities are very important for maintenance of the navigation channels to the harbours. This anthropogenic activity has a strong local and temporal effect on the benthic habitat. The regulation and monitoring of dredging activities have to be continued.

- Fishery

  Fishery activities, mainly beam trawling, pose important anthropogenic impacts on the benthos (see 4.2.7). Heavy beam trawling activities are forbidden in the coastal zone, but shrimp trawling and beam trawling with small vessels are conducted quite intensively along the Belgian coast. A reduction and increased regulation of the fishery activities will help to develop a sustainable and diverse benthic community. In first instance, it is very important to create test sites for the investigation of the effect of reduction or absence off fishery activities in the coastal zone (see topic about research gaps).

- Coastal defence works

  Due to sea level rise and the protection against coastal flooding, coastal defence works (mainly beach nourishment) have been intensified during the last years. This nourishment has a temporary effect on the benthic communities and should be planned and executed in a way that minimizes its environmental impact.

The described activities are within the jurisdiction of the Flemish Government; consultation on a regional and national level should be continued and intensified in relation to these activities.

Direct measures by the Federal Government.

As outlined in the federal coastal management plan, the government has little authority to take direct actions to improve the ecological status of the coast. Some issued actions are outlined below:

➔ Management plans of marine reserves (Special Areas of Conservation (SACs) of the Habitat and Bird Directive, MPA).

Due to the overlap between the WFD zone of the Belgian Coast and some SACs (e.g. Trapegeer-Stroombank, marine part of the Baai van Heist), measures taken within these areas will help to maintain or improve the ecological status of the Belgian coast in regard to both legal frameworks. For the moment, all anthropogenic activities are allowed in these areas (some with licence restrictions) and with some organisations (yachting federation, angle sport federations, union of water sports clubs), user agreements were determined. These user agreements were mainly formulated to raise user awareness on the fauna and flora, to reduce the dumping of litter, to avoid damage of the seafloor, to reduce angling near ship wrecks and to reduce ship traffic in certain periods in the Bird Directive SACs. These user agreements are renewed every three years, without adding extra restrictions to the users.

The following advice related to management plans of marine reserves can be given from a WFD perspective:

- Using these areas as investigation sites for reduction of impact of fisheries (see further).
- Defining clear conservation objectives for these areas, in relation to enforced regulation of activities in these areas. This is currently in progress and needs to be intensified.
- More areas should be designated; this is also in progress.
- The monitoring and evaluation efforts for the WFD and the Habitat and Bird Directive should be integrated for reasons of efficiency.

➔ MMM - law

The MMM law is the only policy instrument of the Federal government to reduce the anthropogenic impact on the marine environment. Consequently, it is advisable to intensify the pollution control at sea and to install an enforcement framework.

➔ The European Marine Strategy Directive

The European Marine Strategy Directive has the aim to obtain a good environmental status of the marine waters towards 2021. The implementation of this directive is in progress and measures taken within this context will influence the ecological status of the Belgian Coast (< 1 nautical mile).

➔ Further improvement (filling gaps) of the global monitoring plan for the Belgian Marine Waters (WFD, EMS, OSPAR, Habitat- and Bird Directive).

In this context, great improvements were made during the last years to fill in and coordinate the biological and chemical monitoring gaps for the Belgian Marine waters. These efforts are the basis ofthe ecological management of the Belgian marine waters under the different European directives. An intensified coordination on a national and international level is advisable.

➔ Research policy.

During the expert meeting, some research questions arose related to the project, which may be tackled via the research policy of the Federal Government.

1) How to explain the moderate status at the east coast? Does the harbour of Zeebrugge, having lead to hydromorphological changes, have a negative influence on the benthic ecological status or were other pressures (e.g. eutrophication) responsible? Before specific measures can be taken, the causes for the benthic changes at the east coast should be investigated. A

comparison with the Dutch area at the Westerscheldt estuary can help to tackle this question.

2) Climate change? Increases of seawater temperature and of river run-off seem to be the main factors induced by climate change. Investigation is needed regarding the extent of their influence on to the ecological status of the benthos along the Belgian coast.
3) What is the effect on benthos of a reduction of the physical impact of beam trawl fishery? There is need for the creation of test areas in the Belgian coastal waters to investigate changesin benthic characteristics resulting from the absence or reduction of differenttypes of trawling.

These research topics are not only relevant in the WFD context, but also arise in the context of the European Marine Strategy.

5.4 Reduction of the environmental objectives

➔ Is this necessary? Can it be postponed to the next river basin management plan?

Reduced environmental objectives can be defined when it seems in the upcoming years that the good ecological status will not be met or maintained towards 2027. Failing to reach the good status at the Belgian coastal waters will probably be related to natural causes, e.g. the low response time of the marine system to the upstream measures (e.g eutrophication).

Based on the outcome of this project, the immediate formulation of reduced environmental objectives does not seem necessary. However, re-evaluation of this question is needed in the next Scheldt river basin district management plan.

➔ How can this be done? Should the good/moderate boundary from the reference data be lowered?

During the expert meeting, it was decided that probably the best way to reduce the environmental objectives is by reducing the good/moderate boundary to the level of the poor/moderate boundary. In other words, the moderate status would be accepted as the good status for the water body. Defining new reference conditions, which reflect a lower standard, does not seem possible, because the determination of the reference conditions in the BEQI concept is based on the fact that they have to reflect the temporal and spatial characteristics of the coastal benthos. No benthic expert can decide how to make selections in this reference data to reflect lower environmental objectives. Therefore, the environmental objectives have to be reduced by changing the boundary levels under the same reference conditions. In this scenario, the coastal managers still have to try to improve the ecological status of the coast by taking the necessary measures.

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